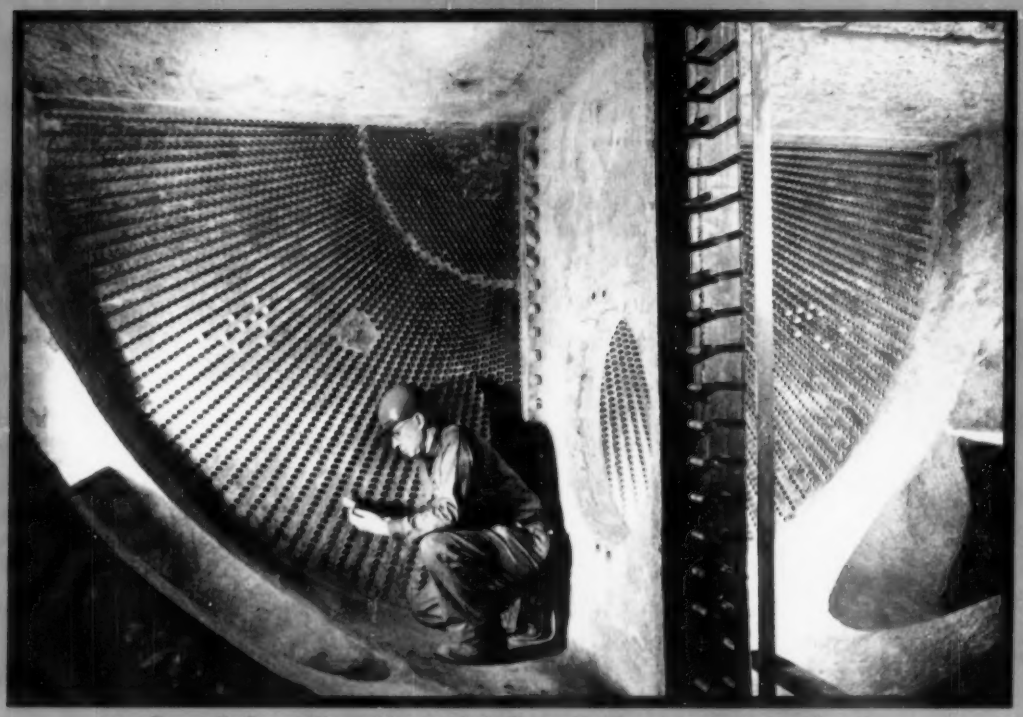
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May 1959



Rivesville Power Plant, Monongahela Power Co., boasts an entire condenser outfitted with stainless steel tubes

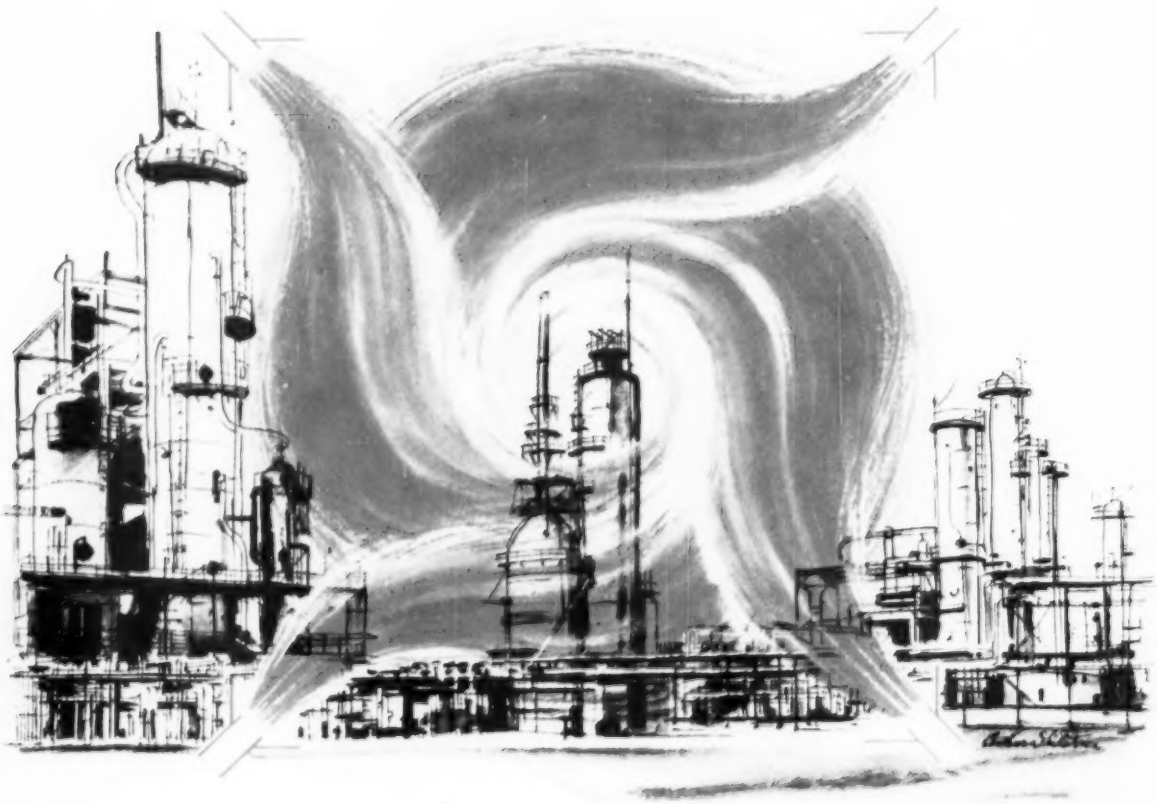
Additives for Oil-Fired Boilers

American Power Conference—I

Gas Turbine for Peak Load Service

Power Plant Clinic

"CREATIVE ENGINEERING" TURNS A TROUBLESOME WASTE INTO A VALUABLE FUEL



Waste carbon monoxide is sentenced to hard labor in the refinery

For years, refinery operators were concerned about the loss of a by-product with an untapped capacity to do work. Produced in volume by their catalyst regenerators, Btu-loaded carbon monoxide was being discharged to the atmosphere for want of a technique to burn it efficiently and productively.

The problem of burning this "lean," moist, toxic gas for the production of steam was not entirely new to Combustion, since the company had designed a large number of boilers to burn a similar fuel – blast furnace gas. Based on this experience, C-E engineers believed that "*tangential firing*" * would be the most effective method of burning carbon monoxide. And so it proved to be. Working in close cooperation with refinery engineers, C-E specialists designed a tangentially-fired boiler which has fully demonstrated its ability to provide the intense turbulence and almost instantaneous combustion needed for the most efficient utilization of this waste product. Today, the C-E "CO" Boiler is providing extra dividends to the refinery industry in the form of steam for power and process.

Here then is another example of **C**reative **E**ngineering–the C-E approach to providing the most advanced designs of boilers for all fuels and steam requirements–from those of small industrial and institutional plants to the largest utility power stations.

* An exclusive C-E development which has been outstandingly successful in burning pulverized coal, oil and gas in hundreds of installations. Involves firing from the four corners of a furnace to create a tornado of flame as illustrated.

"CREATIVE ENGINEERING" is the reason for the leadership attained by C-E products. The products which bear this mark of leadership include:

all types of steam generating, fuel burning and related equipment · nuclear power systems · paper mill equipment · pulverizers · flash drying systems · pressure vessels · soil pipe

COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

C-205

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 30 **No. 11**

May 1959

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ROBERT D. TAFT
Business Manager

JOSEPH C. McCABE
Editor

E. ROBERT LaCROSSE
Circulation Manager

GLENN R. FRYLING
Associate Editor

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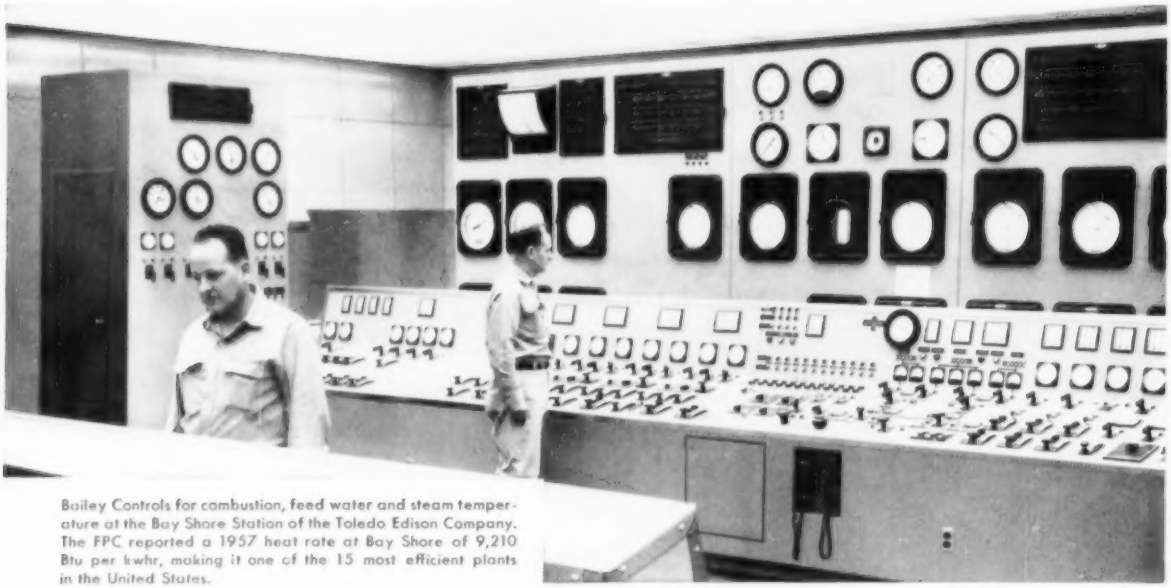


Bailey Controls for combustion, feed water and steam temperature at the Bay Shore Station of the Toledo Edison Company. The FPC reported a 1957 heat rate at Bay Shore of 9,210 Btu per kwhr, making it one of the 15 most efficient plants in the United States.

13 of 15 "most efficient"* power plants depend on Bailey Meters and Controls

Year after year you'll find Bailey Meters and Controls keeping sensitive fingers on the pulse of America's *most efficient* power plants (as rated by the Federal Power Commission.

According to the latest box scores, 10 of the top 15 used Bailey equipment exclusively. There must be a reason. There is! In fact, several:

1. Experience—Bailey Engineers have been making steam plants operate efficiently for more than forty years. They bring you the latest, up-to-the-minute developments in measurement and control.

2. Complete Line—Bailey manufactures a complete line of pneumatic and electric metering and control equipment, proved on thousands of successful installations.

3. Sales and Service—There's a Bailey District Office or Resident Engineer close to you (listed under Bailey Meter Co. in your phone book). Phone for expert engineering counsel.

* 15 MOST EFFICIENT PLANTS • 1957 Heat Rates Reported by the Federal Power Commission

	Btu/kwhr	Meters	Comb. Control	Feed Water Control	Supht. Control
1. Kanawha River (Appalachian Electric Power Co.)	9,118	B	B	B	B
2. Muskingum River (The Ohio Power Co.)	9,139	B	B	B	B
3. River Rouge (The Detroit Edison Co.)	9,140	—	—	—	—
4. Clifty Creek (Indiana-Kentucky Electric Co.)	9,147	B	B	B	B
5. Tanners Creek (Indiana and Michigan Electric Co.)	9,180	B	B	B	B
6. Kyger Creek (The Ohio Valley Electric Corp.)	9,201	B	—	B	B
7. St. Clair (The Detroit Edison Co.)	9,210	B	B	B	B
8. Bay Shore (The Toledo Edison Co.)	9,210	B	B	B	B
9. G. G. Allen (Duke Power Co.)	9,349	B	B	B	B
10. John Sevier (Tennessee Valley Authority)	9,350	—	—	—	—
11. Phillip Sporn (Central Operating Co.)	9,370	B	B	B	B
12. Milliken (New York State Electric and Gas Co.)	9,371	B	—	B	—
13. Shawville (Pennsylvania Electric Co.)	9,396	B	—	—	B
14. El Segundo (Southern California Edison Co.)	9,467	B	B	B	B
15. Colbert (Tennessee Valley Authority)	9,490	B	B	B	B

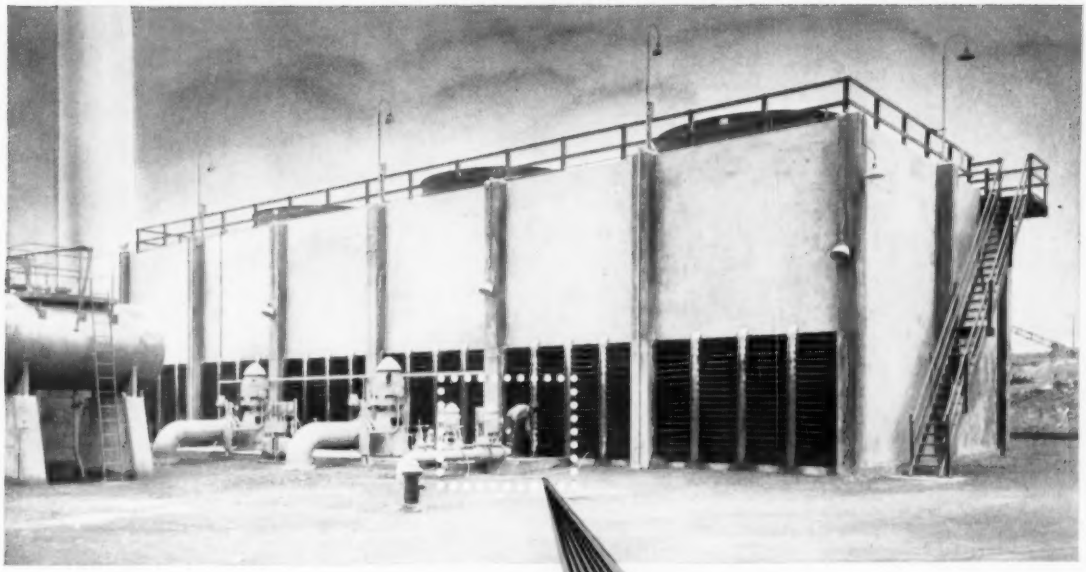
A141-1

Instruments and controls for power and process

BAILEY METER COMPANY

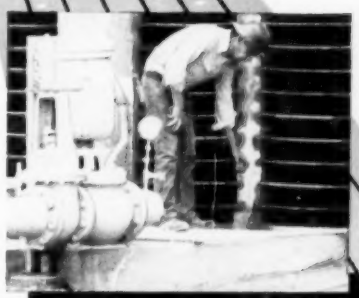
1025 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal



Unusual Cooling Tower gets proven *Nalco* protection

This unusual cooling tower was built for the Riverside Cement Company at Oro Grande, California. The advanced design provides for concrete exterior walls which support and enclose fan units and redwood interior cooling vanes . . . The entire "working sections" of the tower can be repaired or replaced without affecting the structural strength of the shell. Nalco System Treatment protects this cooling system against scale and corrosion — has protected it effectively since it was first put in operation over two years ago. You can get the same complete water treatment protection, promptly, from Nalco. Write for details.



Method of feeding Nalco stabilizing treatment to this system is simplicity itself. Formula is supplied in ball form. Once each shift a perforated tube suspended in the tower basin is filled with balls which slowly dissolve in the cooling water.

NATIONAL ALUMINATE CORPORATION
6234 West 66th Place • Chicago 38, Illinois
CANADA: Alchem Limited, Burlington, Ontario
NORTHWESTERN UNITED STATES, HAWAII and ALASKA:
The Flox Company, Inc., Minneapolis 3, Minnesota
ITALY: Nalco Italiana, S.p.A.
WEST GERMANY: Deutsche Nalco-Chemie GmbH
SPAIN: Nalco Espanola, S.A.

THE *Nalco*® SYSTEM ...SERVING INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE

Nalco CHEMICALS

NEW EDWARD IMPACTOGEAR

What's New from Edward Valves

New Products . . . Solutions to Problems . . . Information on Steel Valves from Edward, Long-Time Pioneer in the Field!

How Impactogear* operates high-pressure valves

You no longer need a crew of men to open or close big, high-pressure valves. New Edward Rockwell-built Impactogear makes big-valve operation a quick and easy job.

FAST AND EASY "RUNDOWN"

Your operator simply applies portable air or electric wrench to pinion shaft-end of Impactogear. When power is applied, pinion turns ring gear, which turns handwheel and moves the stem to "closed" position. Impactor* handwheel then gives final tight shut-off with unique "hammer-blow" action. (Tests show it delivers 12 times the closing force of ordinary handwheels—with less effort!) Impactogear works quickly, can operate a 2500-lb 10" valve (for example) in only 2½ minutes. And Impactogear can be fitted to any 8" or larger Edward valve of 900-lb (or higher) pressure class.

IMPACTOGEAR WITH AIR WRENCH

Impactogear utilizes standard portable air or electric wrenches generally available throughout industry. Example below shows how two typical air wrench ratings can be applied:

Wrench Type No. 1—Stall torque 170 ft-lbs: Free speed 225 rpm; Weight 12 lbs

For 12" and 14" 2500 lb. valves, operating pressures to 3500 psi

For 10" 2500 lb valves, all allowable operating pressures

For 10", 12" and 14" 1500 lb valves, all allowable operating pressures

For 12" and 14" 900 lb valves, all allowable operating pressures

Wrench Type No. 2—Stall torque 200 ft-lbs: Free speed 300 rpm; Weight 38 lbs

For 12" and 14" 2500 lb valves, operating pressures 3500 psi to 4500 psi

IMPACTOGEAR WITH ELECTRIC WRENCH

Portable electric wrenches are equally practical. Example below shows a typical electric wrench rating as applied to Impactogear:

Wrench Type No. 1—Stall torque 176 ft-lbs: Free speed 225 rpm; Weight 44 lbs

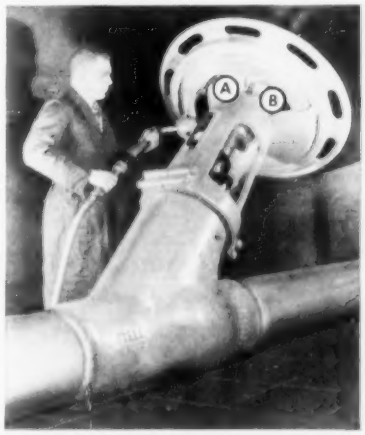
For 10" 2500 lb valves, all allowable operating pressures

For 10" and 12" 1500 lb valves, all allowable operating pressures

For 12" and 14" 900 lb valves, all allowable operating pressures

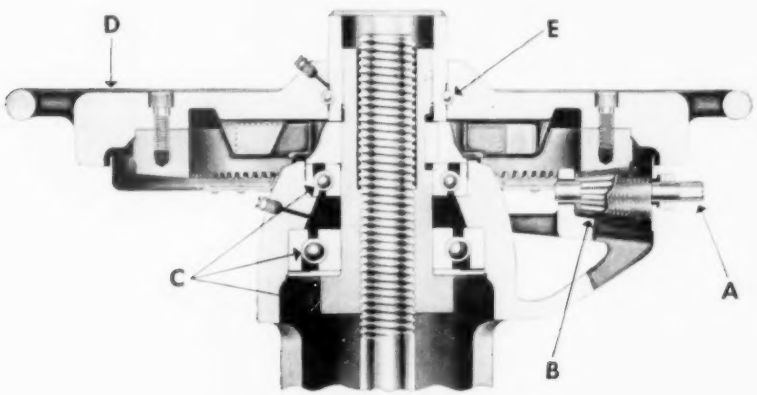
SLASH COST OF VALVE OPERATION

Individually installed operating motors are a big investment. They can add as much as 100% to the basic valve cost. *But now you can save that money by standardizing on Impactogear*—radically simple, thoroughly dependable mechanism utilizing *existing* compressed air or electric facilities. Your Edward Representative will be glad to provide full details and help you determine how Impactogear can work to your best advantage. Contact him—or write *Edward Valves, Inc., 1206 W. 145th Street, East Chicago, Indiana.* (Subsidiary of Rockwell Manufacturing Company). Represented in Canada by Lytle Engineering Specialties, Ltd., 360 Notre Dame St., W., Montreal 1, Quebec.



LIGHTWEIGHT PORTABLE WRENCH can operate as many Impactogear-equipped valves as desired. Or, each valve can be fitted with its own wrench. Either way, you get lower operating costs. Final closing is effected by handwheel lugs (A) striking hammer blows against cross arm keyed to yoke bushing (B). Half of gear cover was removed for illustration purposes.

*T.M. Reg. U.S. Pat. Off.



Details of new Impactogear and Impactor Handwheel:

A—Hex head of pinion gear shaft. Power wrench is applied here. B—12-to-1 bevel gear ratio is typical for median size handwheel. C—Exclusive EValthrust yoke bushing combines radial and thrust bearings for easy operation and long life. D—New Impactor handwheel concentrates mass near outer circumference for maximum impacting efficiency. E—New extra bearing increases operating efficiency.

EDWARD STEEL VALVES

another fine product by

ROCKWELL

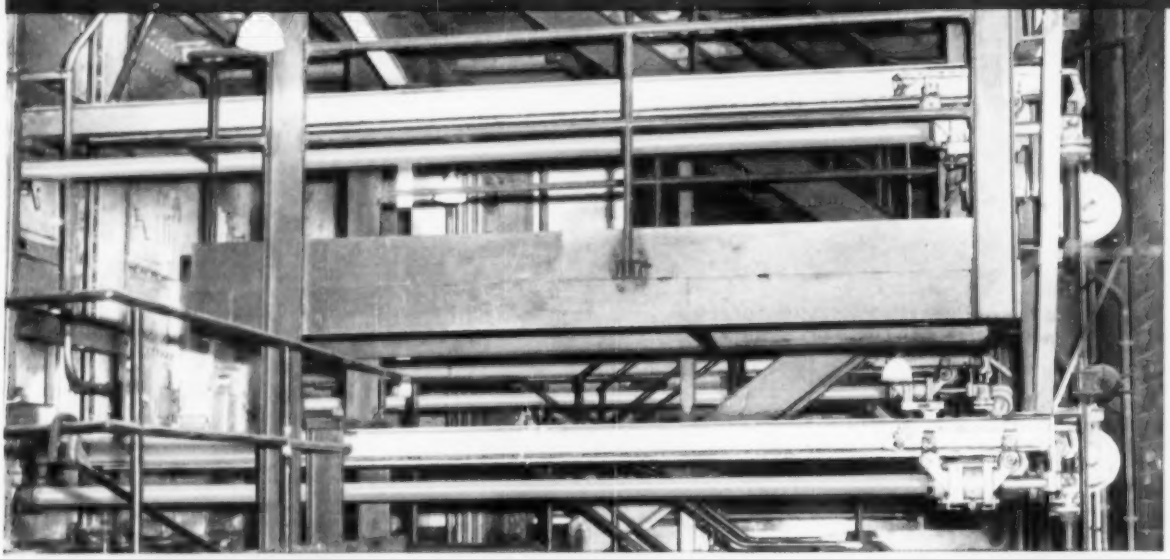
Catalog 14 contains full data on the complete Edward line of forged and cast steel valves from ¼" to 18", in globe and angle stop, gate, non-return, check, blow-off, stop check, relief, hydraulic, instrument, gage and special designs; for pressures up to 10,000 lbs. with pressure-seal, bolted, union or welded bonnets, with screwed, welding or flanged ends.

AT F.M. TAIT STATION, DAYTON POWER & LIGHT CO.

BOILER CLEANING IMPROVEMENT HELPS MODERNIZATION PROGRAM

SAVE $40,000

DIAMOND BLOWERS and AUTOMATIC



Three of the Diamond Model IK Long Retracting Blowers installed to replace manually operated rotary blowers. Electric motor driven, they are controlled by the Automatic Sequential Panel. Air is used as the blowing medium. Rotary elements were retained in cooler locations and motorized for automatic operation and are also controlled by the Automatic Sequential Panel.

In the continuous struggle to cut operating costs, the Dayton Power & Light Co. has found a very useful tool in "Boiler Cleaning Modernization."

By applying the latest soot blowing equipment to four of their boilers at the F. M. Tait Station, together with other features of the modernization program, the Dayton Power & Light Co. was able to reduce the operating costs on these boilers by some $40,000 per year and also cut blower maintenance costs.

On the first boiler that had its cleaning modernized, 17 rotating elements were removed; the remaining seven blowers of this type were electrified for automatic control. The cleaning equipment added consisted of five Long Retracting Blowers and six Short Retracting Blowers. All blowers are automatically controlled by a Diamond Selectromatic Panel.

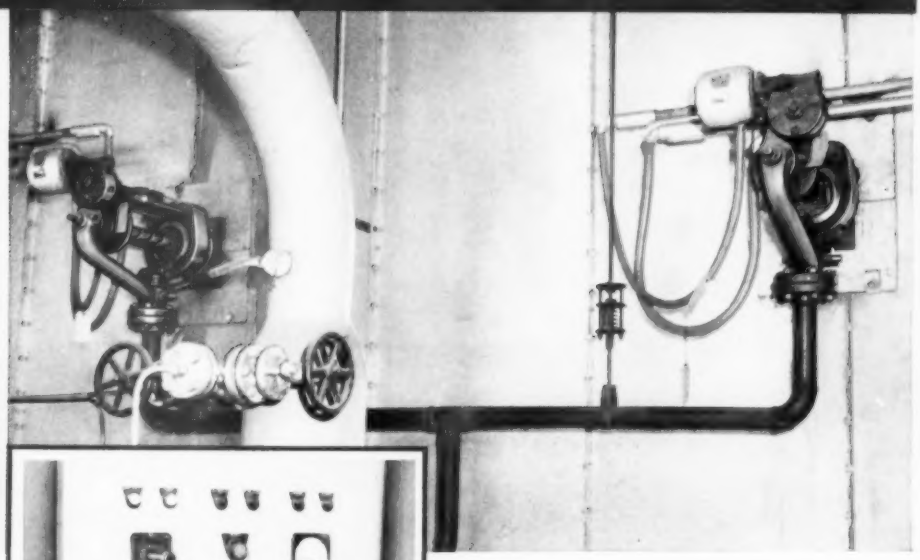
This is one of many examples of the savings possible by improvements now available in Diamond Blowers and Automatic Sequential Control. Over the years Diamond has engaged in continuous aggressive research in boiler cleaning. This research has paid off in improvements that save you money and improve your operation.

Let us make a study of your boiler cleaning . . . perhaps similar savings can be suggested.

Per Year in Operation

and Cut Blower Maintenance Costs

SEQUENTIAL CONTROL PANEL



Two of the air blowing Model IR short retracting wall blowers with electric automatic operation.

Diamond Automatic Sequential Control Panel installed as part of the modernization program at the F. M. Tait Station. This panel automatically operates each blower in turn until the blowing cycle is complete. Any individual blower may be operated independently by simple turning switches. Cleaning program is set up by switches. Operator starts — thenceforth operation is automatic.

Diamond

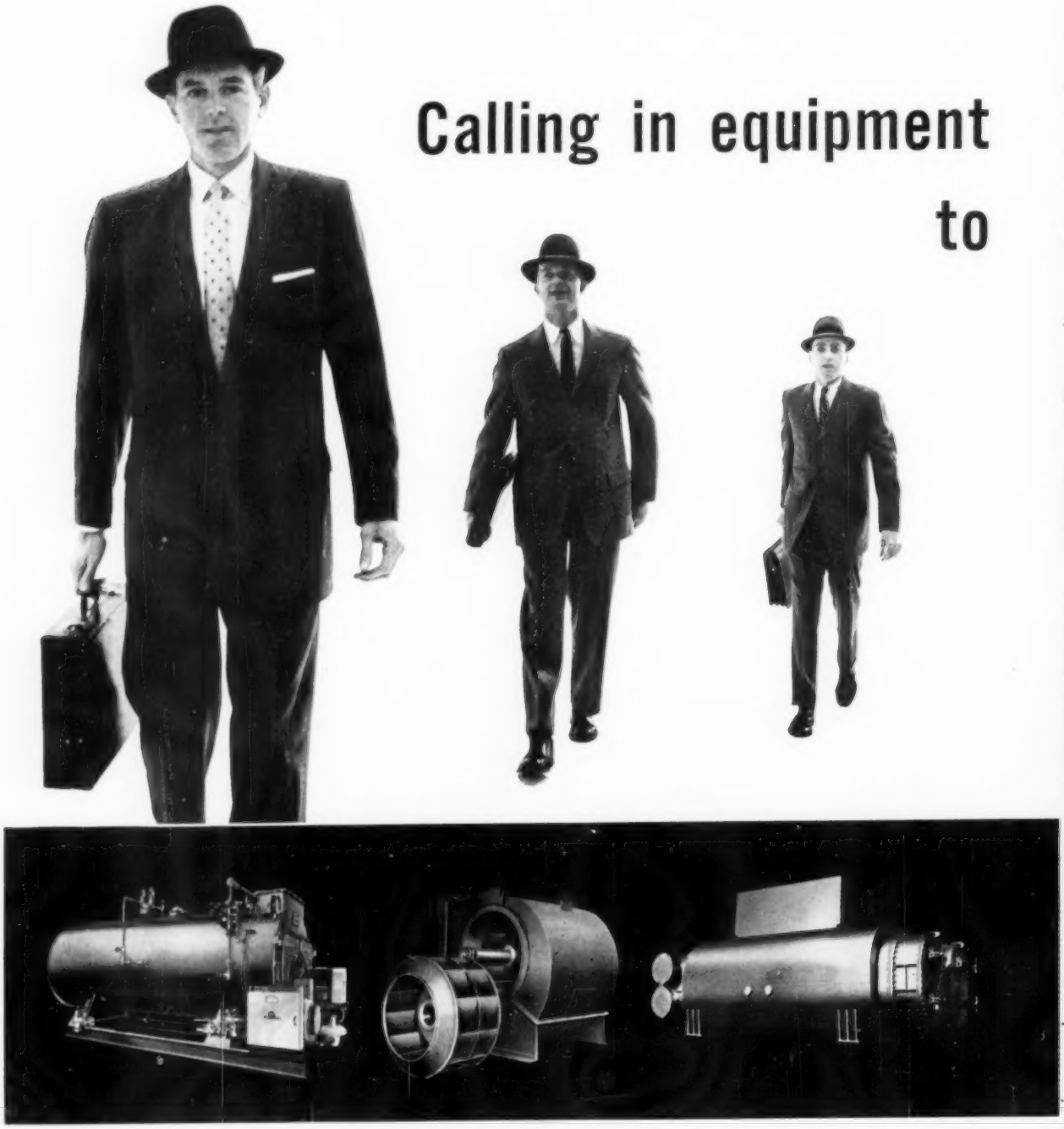
DIAMOND POWER SPECIALTY CORP.

LANCASTER, OHIO

6243

DIAMOND SPECIALTY LIMITED • WINDSOR, ONTARIO

Calling in equipment to



Firebox, scotch-type, and package boilers for heat, steam, and industrial power.

Mechanical draft fans for induced and forced draft duty in power plants.

Balanced-flow surface condensers for condensing turbo-generator exhaust steam.

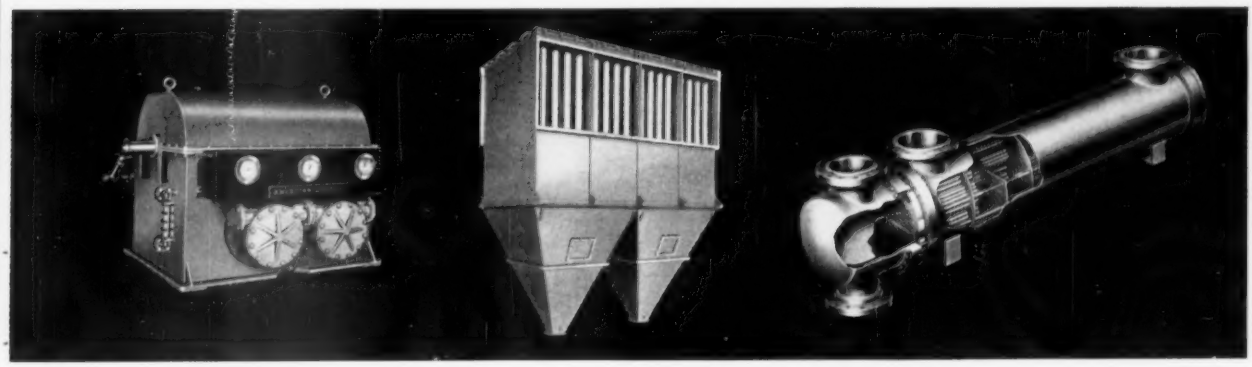
One call for all

representatives discuss specifications?

Be sure one of the representatives you call is from

AMERICAN-Standard Industrial Division

You benefit by discussing equipment-selection with an engineer. American-Standard* Industrial Division is engineer-staffed from brass to branches. Combining three American-Standard divisions – American Blower, Ross Heat Exchanger, Kewanee Boiler – this new organization offers *one-source responsibility* for quality and performance in equipment designed, engineered, and manufactured to work together. There are offices in all principal cities to assist you – from the planning stage on. Contact the one nearest you. American-Standard Industrial Division, Detroit 32, Mich. In Canada: American-Standard Products (Canada) Limited, Toronto, Ontario.



Fluid drives for adjustable-speed control of feed-pump flow and fan volume.

Dust collectors and precipitators for recovering fly ash, eliminating dust.

Standard and engineered heat exchangers and feedwater heaters for every duty.

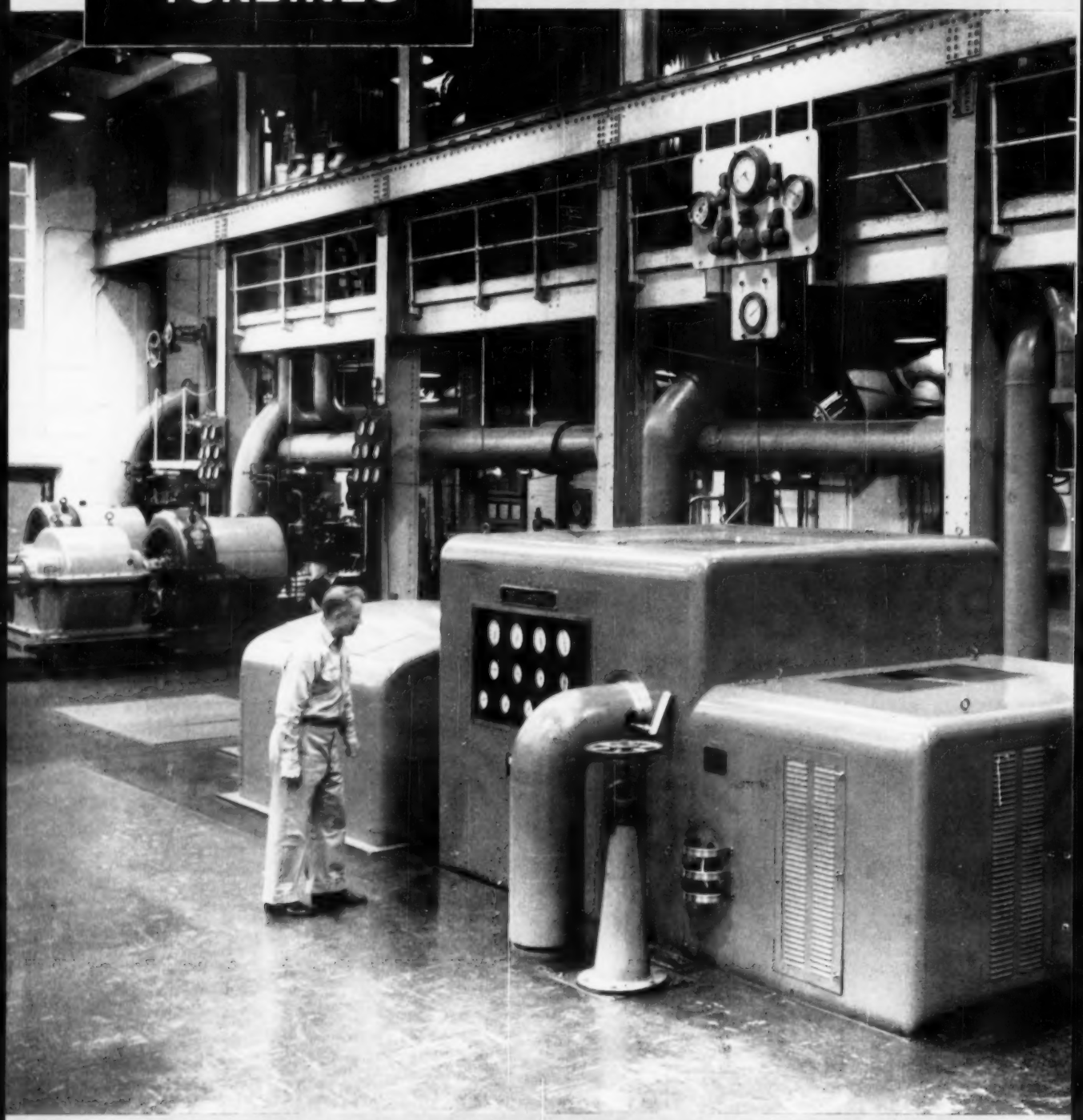
*AMERICAN-Standard and Standard are trademarks of American Radiator & Standard Sanitary Corporation.

AMERICAN-Standard
INDUSTRIAL DIVISION

AMERICAN BLOWER PRODUCTS • ROSS PRODUCTS • KEWANEE PRODUCTS

DE LAVAL STEAM TURBINES

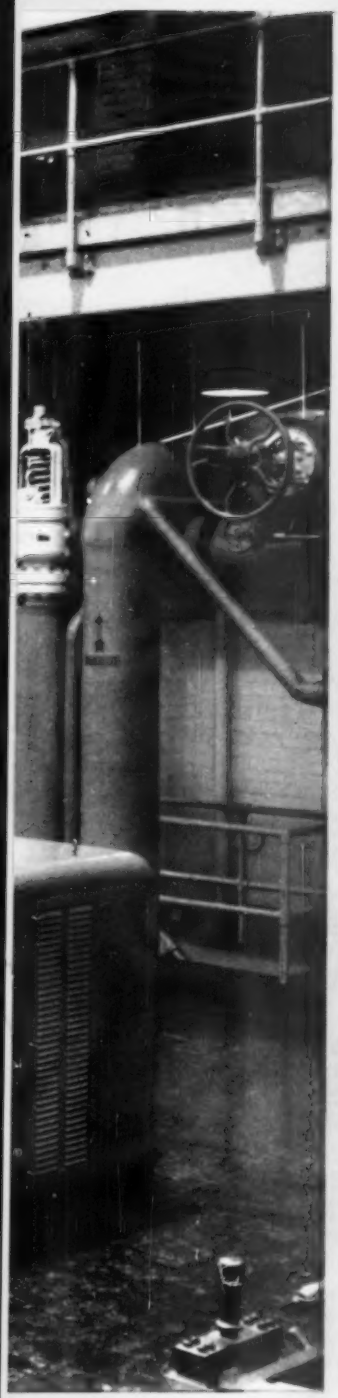
for process industries



The photograph above shows a De Laval direct-connected turbine generator installation at Parke, Davis & Co., Detroit, Michigan.

This controlled extraction, controlled back-pressure unit supplies 2000 kw using process steam. Extraction is at 130 psig, exhaust is 5 psig. This new machine was added to already existing De Laval units that have been in service for 30 years. In addition, the Parke-Davis research Laboratories in Ann Arbor, Michigan will soon be using a new 1000 kw unit.

DL-449



Parke, Davis & Co. uses DE LAVAL Steam Turbines for process and power generation

Proved economy, dependable service

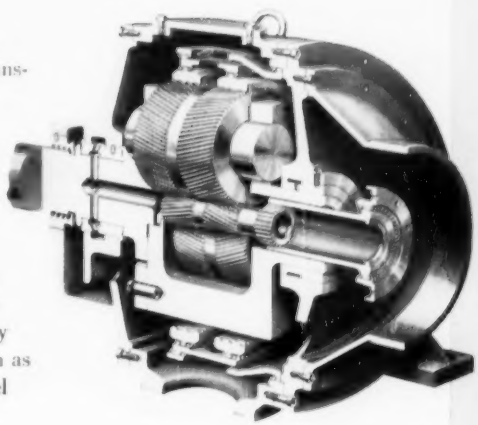
In many process industries, an important by-product is economical electric power. If appreciable quantities of process steam are used, power generation can be achieved at comparatively low cost.

De Laval, pioneer in high speed rotating machinery, has continued to maintain engineering and manufacturing leadership. If you have process application where low-cost power generation can be utilized, call on De Laval.

De Laval-Stoeckicht Planetary Gears

In many applications where high speed and high horsepower are transmitted, the De Laval-Stoeckicht planetary gear can be used to great advantage. It is also used as a speed increaser or decreaser in many industrial installations.

Among its outstanding characteristics are light weight, in-line construction and space saving. It may be used for all kinds of drives such as gas turbines, steam turbines, diesel engines, etc.



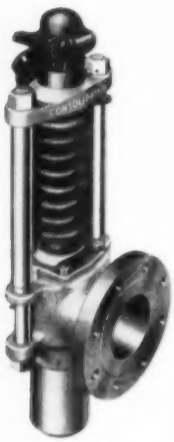
Write for Bulletin 2400

DE LAVAL *Steam Turbine Company*

886 NOTTINGHAM WAY, TRENTON 2, N. J.

STOPS VALVE LEAKAGE

at high pressures



Consolidated "Maxiflow" Safety Valve, Type 1700 Series, Sizes: 1½" thru 6".

The Thermodisc Seat in Consolidated "Maxiflow" Safety Valves solves the problem of valve leakage at high pressures, saves steam and reduces maintenance.

Research has shown that when a safety valve on high pressure service reseats after popping, a small amount of leakage occurs momentarily between seat and disc before the valve seals off and becomes tight. This leakage is comparable to steam flow through small, individual orifices.

When a small steam leak exists at some point on the valve seat, the area near the point is cooled by the refrigeration effect of the escaping vapor. The metal tends to contract causing slight deformation of the seat. This acts to increase the gap size between disc and seat bushing at the leakage point. The size of the gap increases rapidly until the rate of leakage becomes extremely high.

The Thermodisc Seat prevents seat distortion and consequent leakage with a seat element recessed to form a thin wall at the area of seat contact. This design permits a high rate of heat-transfer in the metal *that eliminates all thermal differences.*

The result is a degree of tightness, essential to the operation of safety valves in high pressure services, never previously achieved. For complete details, write for Bulletin 707B.

MANNING MAXWELL & MOORE INC. TRADE MARK

CONSOLIDATED SAFETY VALVES

A product of

MANNING, MAXWELL & MOORE, INC.

Consolidated Ashcroft Hancock Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

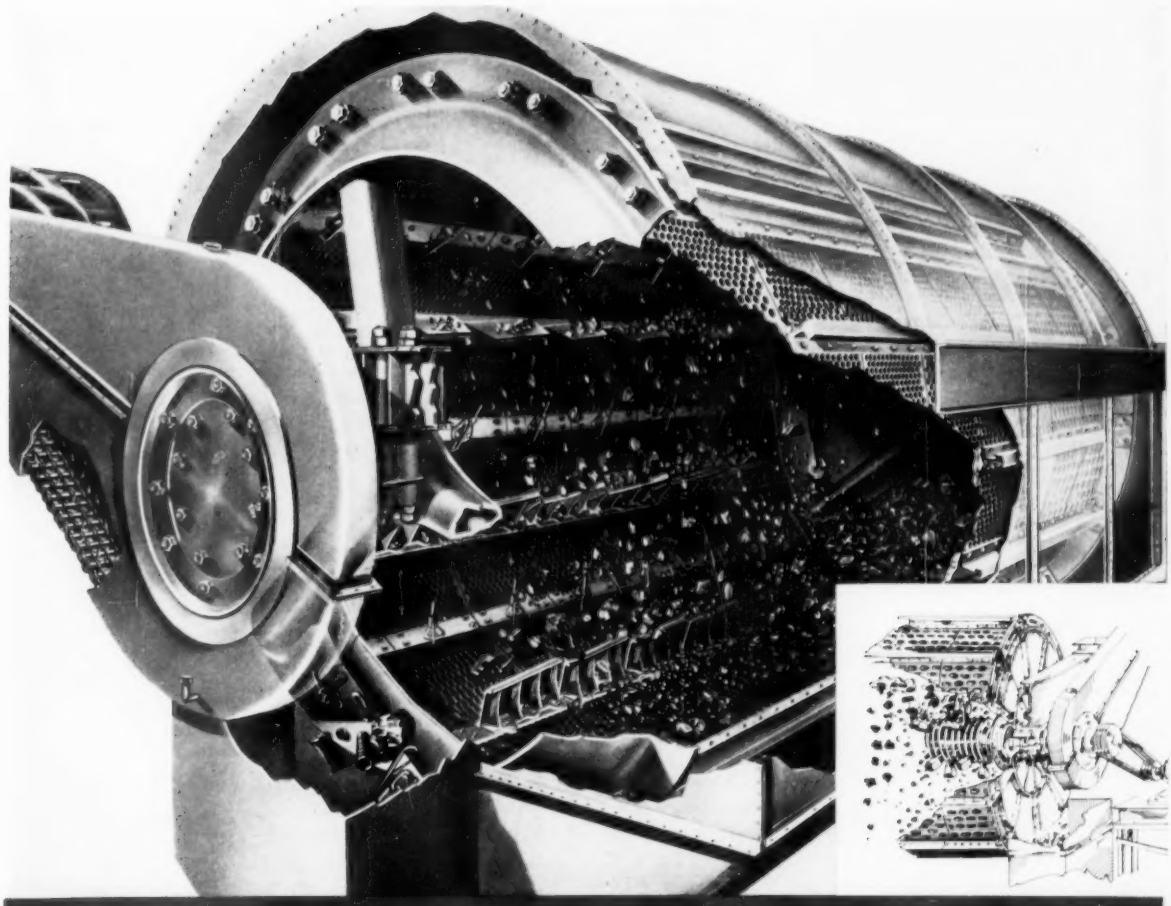


Illustration of modern Pennsylvania Bradford Breaker in operation. Note coal lifted and dropped for gravity impact breaking across high-performance sieve steel. Tramp iron and other refuse automatically discharged.

It cleans coal as it crushes AT NO EXTRA COST

The Pennsylvania Bradford Breaker has no peer in the preparation of run-of-mine coals. This is borne out by the fact that Pennsylvania Bradfords condition over 38 million tons of coal annually in power plants all over the world. This has been going on for many, many years and it's your assurance of dependability. For the preparation of extra hard coals the Pennsylvania Bradford Hammermill is usually preferred. This crusher is a Bradford Breaker with a swing hammer rotor placed at the discharge end that reduces all oversize so it can pass thru the cylinder perforations, thus eliminating any waste of oversize that otherwise might pass out the discharge end.

For complete information on these Breakers, ask for Bulletin 3009. Pennsylvania Crusher Division, Bath Iron Works Corporation, West Chester, Pennsylvania.

Penn CRUSHER

Hall Industrial Water Report

VOLUME 7 MAY 1959 NUMBER 3

Take the Simpler Things in Life

What could be simpler than water, air, salt? Or more essential to life? Yet they can destroy steel, copper and other common metals and alloys used extensively in industry.

The Hall engineer is trained to recognize corrosion problems in the making and how to combat them. He can help you locate trouble spots and recommend corrective measures before serious damage has been done. That is one of the reasons why the services of Hall engineers are in demand wherever water is used for boilers, cooling, process or general service.

Corrosion Slows Production

When Hall engineer W. E. Pfeiffer visited a new client he was immediately handed a costly problem. When the weather became extremely cold the part of the plant farthest from the boiler house could not be kept comfortably warm, so that the assembly line had to be slowed.

Although repairs to the condensate return system had been minor, Pfeiffer suspected that corrosion products were interfering with heat transfer and proper circulation in the heating system. His suspicion was confirmed when it was shown that condensate was dissolving iron from the piping.

To control further corrosion and to disperse existing corrosion products, Pfeiffer recommended addition of filming amine (Hagafilm®) to the boiler feed water. As the amine distilled out of the boiler with the steam, it loosened corrosion products and laid down a protective film on the metal surfaces wherever steam condensed. With the initial cleanup period over, heating the whole plant is no longer a problem.

Seeing Spots

A Washington hospital reported to Hall engineer W. R. Greenaway that contamination of steam used in autoclaves was spotting stainless steel surgical instruments plated with chromium and nickel. By examining the instruments with a microscope, Greenaway found the problem was indeed serious. The spots were not just stains, they consisted of clusters of tiny pits.

Corrosion of stainless steel pointed to chloride. None was found in condensed steam samples. Only negligible amounts were present in the water and detergent used for washing. As a last resort Greenaway rinsed with distilled water the cloth used to wrap the instruments. A check on the washings proved the cloth to be the source. Condensing steam in the autoclaves extracted enough chloride from the cloth to cause the difficulty.

The job wasn't quite complete. A trip to the laundry was necessary. There it was found that a compound used in the last rinse was high in chloride. Since this has been omitted there has been no further trouble.

Red Carpet Treatment

Stains and poor dyeing caused by iron oxide plagued a Southern carpet factory. Thousands of yards of woolen yarn had to be reworked and sold at substandard prices.

The call went out for a Hall engineer. H. V. Gedney's quick check of the wash water from the scouring lines showed it to be deep red in color. He then surveyed the plant water system from the intake to the trouble points. After clarification the water was satisfactory. But corrosion increased iron content gradually from the filters through the water heater, storage tank and service lines.

With the problem in focus, Gedney had the plant start threshold treatment for corrosion control with Calgon® Composition TG. The red water problem was stopped almost immediately.

Serious water problems can't always be solved in one day. However, the Hall engineer's training and experience enable him to get at the cause of most troubles quickly.

Water is your industry's most important raw material. Use it wisely.

Protective Coatings

Successful application of most coatings to water storage tanks is limited by several factors: water temperature, coating porosity, abrasion and water contamination. But maintaining the continuity of a coating on submerged portions of tanks is extremely important. The tanks are subjected to an oxygen concentration cell type of attack which tends to center corrosion at breaks in the coating. This can cause rapid perforation instead of slow, even corrosion of the total surface.

The organic barriers can be grouped into three large categories: Elastomers include the natural rubber and synthetic products like neoprene. Thermosetting resins cover the alkyd, phenolic and epoxy groupings plus the newer silicones. Thermoplastic materials embrace the vinyl and vinylidene chlorides and polyethylene plus the various coal tar and asphalt base bitumens. Combinations of various resins, resins and metallics, and resins and bitumens are being used extensively.

In many cases, a coating gives unsatisfactory service because it is not applied properly. All corrosion products and other foreign matter must be removed from the surface to be coated. Sandblasting and wire brush cleaning generally work out better than chemical cleaning unless afterrusting can be prevented.

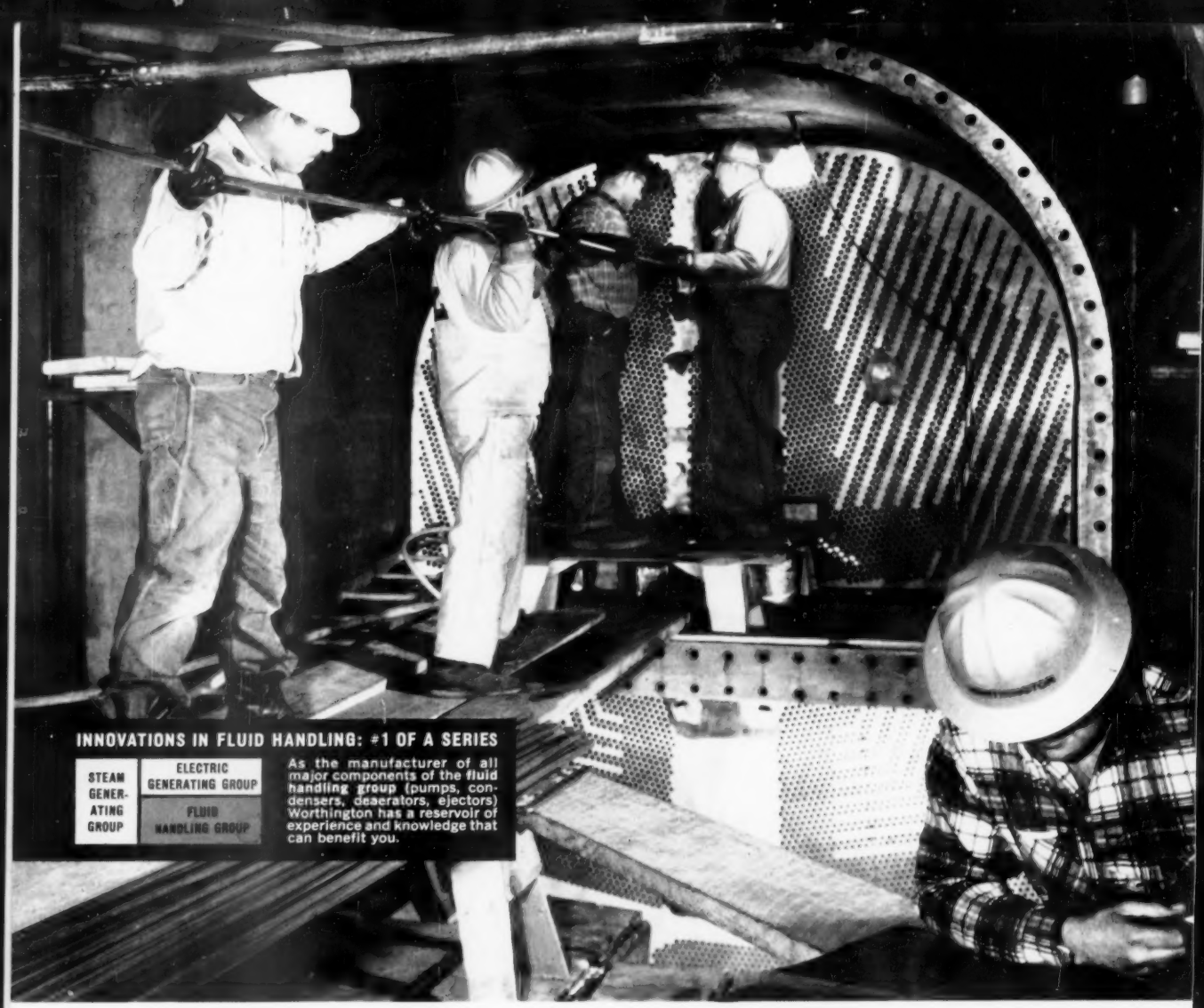
To summarize, protective coatings can frequently be used to protect water tanks if the proper material is used and adequate care is taken in cleaning the metal surfaces and in applying the material.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information on how the Hall System can help you solve your particular water problems, write, wire or call address below.

HALL LABORATORIES
DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PA.
In Canada: Hagan Corporation (Canada) Limited, Toronto

Hall Laboratories—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water


INNOVATIONS IN FLUID HANDLING: #1 OF A SERIES
STEAM GENERATING GROUP
ELECTRIC GENERATING GROUP
FLUID HANDLING GROUP
As the manufacturer of all major components of the fluid handling group (pumps, condensers, deaerators, ejectors) Worthington has a reservoir of experience and knowledge that can benefit you.

NUCLEAR CONDENSER

Dresden unit is tailored to special needs of nuclear plants

Engineers of General Electric, Worthington and Bechtel Corporations worked together closely with Commonwealth Edison on new Dresden Station.

Four major problems faced Worthington in the design of a 120,000 sq. ft. condenser for the Dresden Nuclear Power Station being built by General Electric Co. for Commonwealth Edison Co. and the Nuclear Power Group, Inc. They were: (1) necessity of handling full output of dump steam, (2) quantities of free gases in the steam, (3) maintaining condensate purity, and (4) providing radioactive decay time for the condensate.

Worthington engineers, working in close cooperation with the customer, his design engineers and contractors, solved these problems. To handle dump steam, pressure breakdown devices were installed in the condenser itself and in a special "blister" on one side of the condenser. An extra large ejector was used to handle quantities of free gases. And to maintain condensate purity double tube sheets were used and special deaeration features were provided.

Radioactive decay time was provided by means of the special hotwell which is baffled to make the transit time of the condensate long enough to allow short-lived radioactive impurities to decay to lower levels.

This typical example shows you how Worthington applies its experience as a manufacturer of all major components of the fluid handling group in solving the problems of one particular element. To put this progressive "know how" to work on your power plant problems, conventional or nuclear, contact your nearest Worthington district office. Or write to Worthington Corporation, Section 45-8, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantford, Ontario.

WORTHINGTON

POWELL

LUBRICATED

PLUG VALVES

from [illegible] boiler house could not be kept comfortably warm, so that the assembly line had to be slowed.

Although repairs to the condensate return system had been minor, Pfeiffer suspected that corrosion products were interfering with heat transfer and proper circulation in the heating system. His suspicion was confirmed when it was shown that condensate was dissolving iron from the piping.

To control further corrosion and to disperse existing corrosion products, Pfeiffer recommended addition of filming amine (Hagafilm®) to the boiler feed water. As the amine distilled out of the boiler with the steam, it loosened corrosion products and laid down a protective film on the metal surfaces wherever steam condensed. With the initial cleanup period over, heating the whole plant is no longer a problem.

Seeing Spots

A Washington hospital reported to Hall engineer W. R. Greenaway that contamination of steam used in autoclaves was spotting stainless steel surgical instruments plated with chromium and nickel. By examining the instruments with a microscope, Greenaway found the problem was indeed serious. The spots were not just stains, they consisted of clusters of tiny pits.

Corrosion of stainless steel pointed to chloride. None was found in condensed steam samples. Only negligible amounts were present in the ste[illegible]e auto[illegible]ves extract. I enough chloride from the cloth to cause the difficulty.

The job wasn't quite complete. A trip to the laundry was necessary. There it was found that a compound used in the last rinse was high in chloride. Since this has been omitted there has been no further trouble.

Red Carpet Treatment

Stains and poor dyeing caused by iron oxide plagued a Southern carpet factory. Thousands of yards of woolen yarn had to be reworked and sold at substandard prices.

The call went out for a Hall engineer. H. V. Gedney's quick check of the wash water from the scouring lines showed it to be deep red in color. He then surveyed the plant water system from the intake to the trouble points. After clarification the water was satisfactory. But corrosion increased iron content gradually from the filters through the water heater, storage tank and service lines.

With the problem in focus, Gedney had the plant start threshold treatment for corrosion control with Calgon® Composition TG. The red water problem was stopped almost immediately.

Serious water problems can't always be solved in one day. However, the Hall engineer's training and experience enable him to get at the cause of most troubles quickly.

Water is your industry's most important raw material. Use it wisely.

neo[illegible]rene, [illegible]rmosetting resins cover the alkyd, phenolic and epoxy groupings plus the newer silicones. Thermoplastic materials embrace the vinyl and vinylidene chlorides and polyethylene plus the various coal tar and asphalt base bitumens. Combinations of various resins, resins and metallics, and resins and bitumens are being used extensively.

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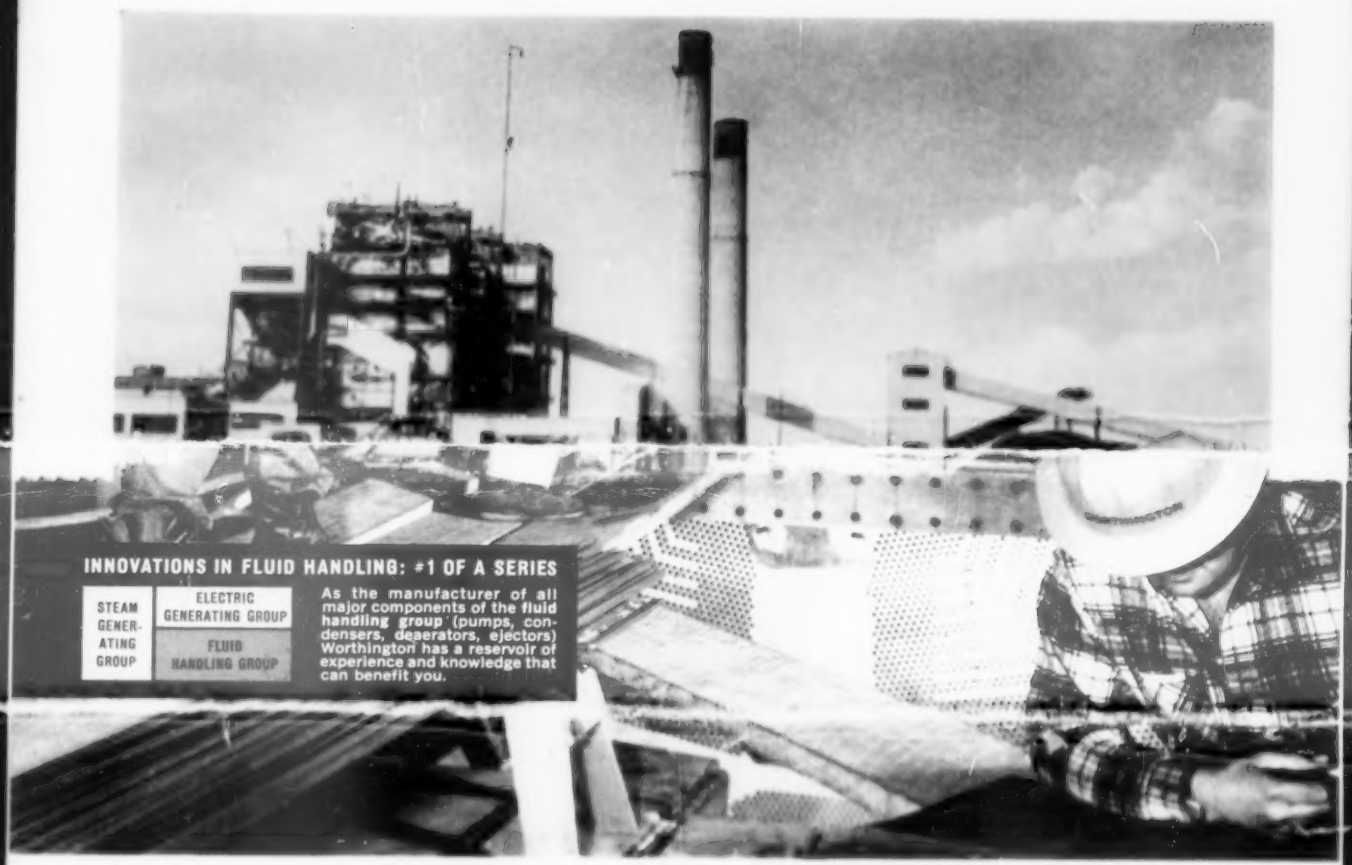
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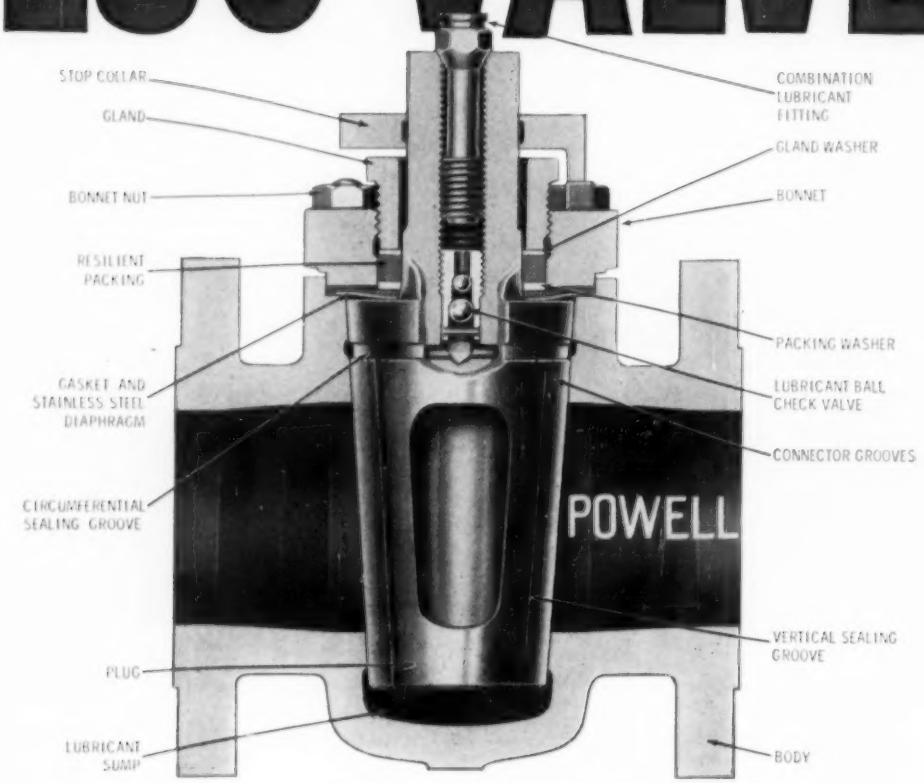
WORTHINGTON

POWELL

LUBRICATED PLUG VALVES



Sectional view Powell Screwed Gland Lubricated Plug Valve.

Like all Powell Valves, Powell Lubricated Plug Valves are superior in their field . . . and have many advantages over other conventional types of Valves.

- Simple design: only three basic parts—Body, Bonnet, Plug.
- Quick, complete shut-off—a quarter turn will close or open the valve.
- Tapered Plug assures positive seating.
- Machined surfaces of plug and body are not exposed in the open position. Any media adhering to the plug when in the closed position is removed when plug is rotated.
- Cavity-free straight passage assures streamlined flow in either direction. Scale and sediment cannot collect.

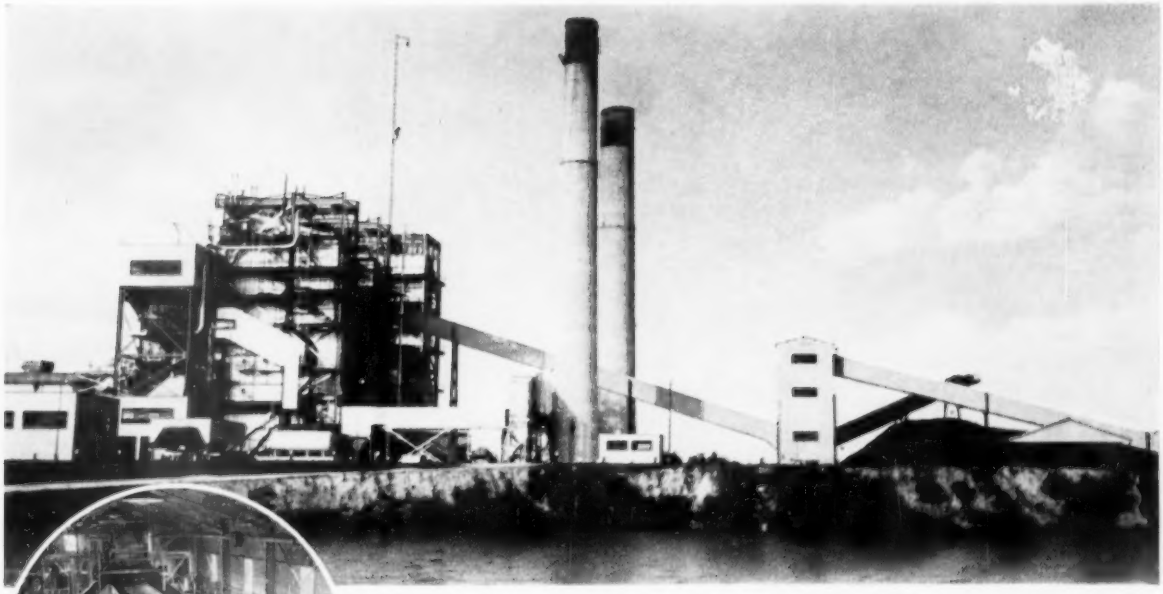
Powell Lubricated Plug Valves are available in sizes ½" through 16", depending on the type required—Semi-steel 175 and 200 pounds WOG;—Carbon Steel ASA 150 and 300 pounds.

Powell can also furnish Lubricated Plug Valves in other alloys on special order.

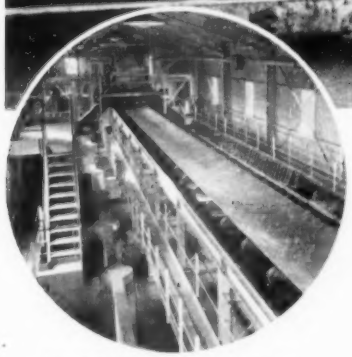
For all your valve needs, make it a policy to consult your local Powell Distributor—or write directly to us.

THE WM. POWELL COMPANY

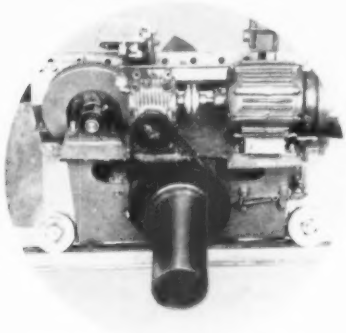
Dependable Valves Since 1846 • Cincinnati 22, Ohio



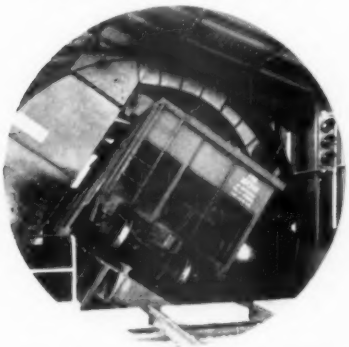
H & P Built the Complete Coal Handling System for Carolina Power & Light Company's Lumberton Station. Engineers & Constructors: Ebasco Services Incorporated.



H & P Coal Conveyor and Tripper



Reciprocating Thorsten Coal Sampler



H & P Rotary Railroad Car Dumper with Integral Electronic Scale (Pat. Pend.)

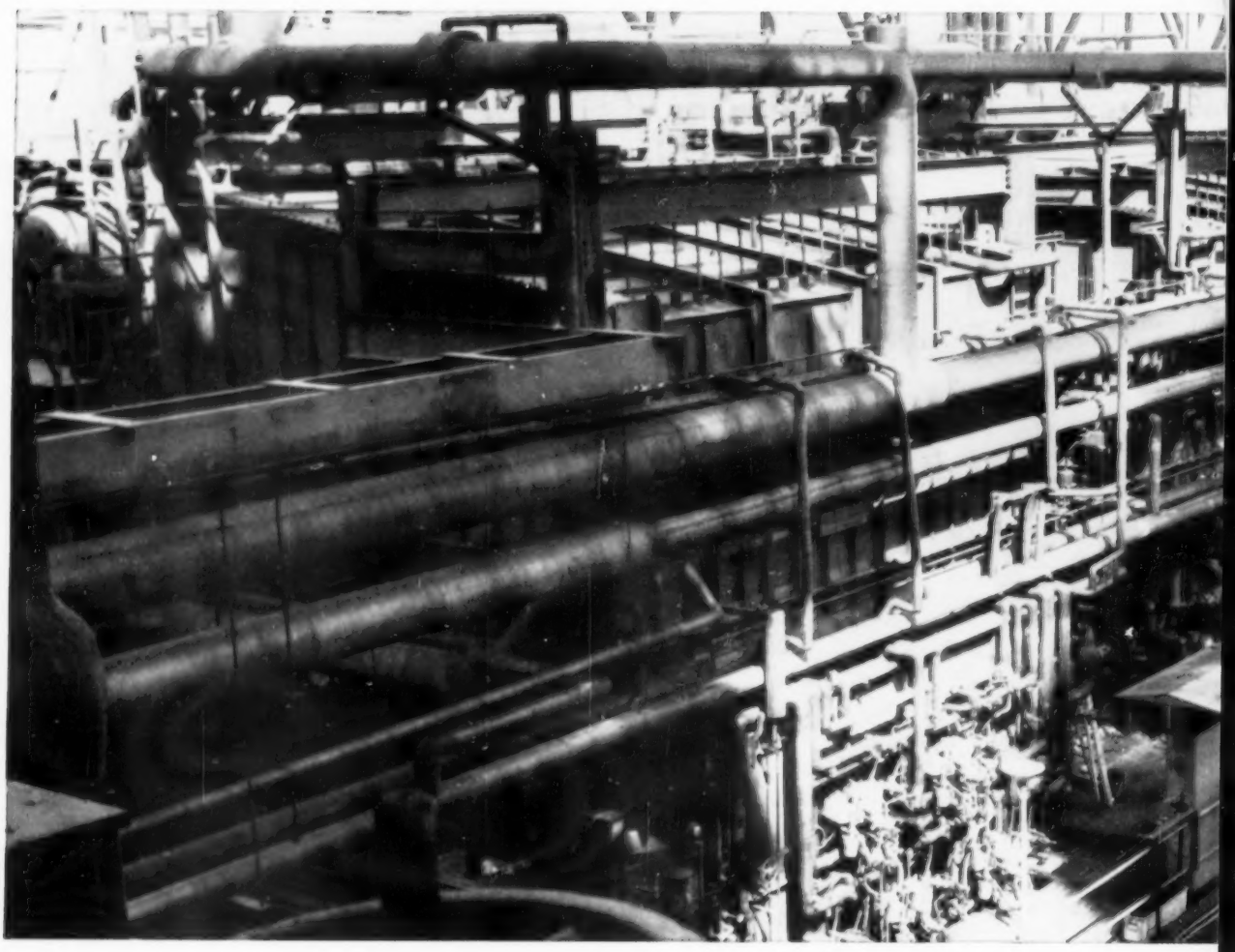
COMPLETE COAL HANDLING BY H&P

Place yourself in experienced hands for your next barge or railroad car unloading requirements; your coal conveying or distribution problems; or for your completely new Coal Handling System. Request an H & P Contracting Engineer to assist in developing a practical method of unloading and handling your coal.

Heyl & Patterson has a reputation for building reliable and efficient bulk material handling equipment. This has been recognized by numerous Consulting Engineers who have placed their trust in H & P's ability to serve their clients well.

Heyl & Patterson INC.

55 FORT PITT BLVD., PITTSBURGH 22, PA., COurt 1-0750



Copes-Vulcan boiler control load conditions at Deepwater

In addition to producing power for the Atlantic City Electric Company system, the Deepwater plant delivers steam to an adjacent chemical plant for process use.

To meet the widely fluctuating process demands, Copes-Vulcan controls the two low pressure boilers with precision responsiveness. Each boiler has a maximum continuous rating of 150,000 pounds per hour at 230 psig saturated. The system consists of:

Combustion Control maintaining a constant pressure in the main process steam header by holding steam output from the boiler equal to steam demand.

Copes-Type 3-L Feedwater Control modulated by three control influences—steam flow, feedwater flow and drum water level.

Boiler feed pump recirculation control protecting the boiler feed pumps against overheating on light loads.

Vulcan Rotary Soot Blowers providing positive cleaning over the full blower arc, which may be as much as 360 degrees.

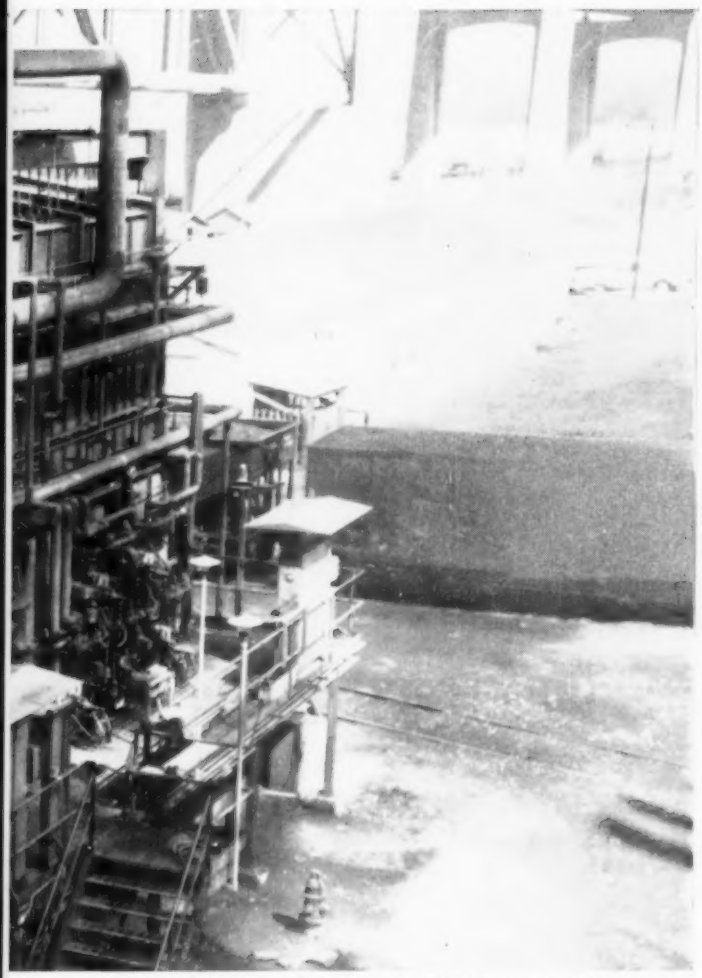
The system controls all equipment with either one or two boilers in service, permits each boiler to carry a different load. Control is automatic through a load range of 20,000 to 200,000 pounds per hour.

Whether your boiler is large or small, power or process, Copes-Vulcan can provide a unit or an integrated package, custom designed to your requirements. **For details on the Deepwater Station installation, write for Bulletin 1057.**

COPES VULCAN

Copes-Vulcan Division
BLAW-KNOX COMPANY • Erie 4, Pennsylvania

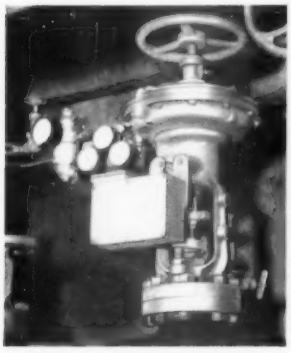
BLAW-KNOX



Outside boilers and boiler controls subject to severe weather, with temperatures as low as 10° F. Except for the central control panel and relays and controllers mounted on it, the Copes-Vulcan control system is entirely outdoors.

meets unusual

Station

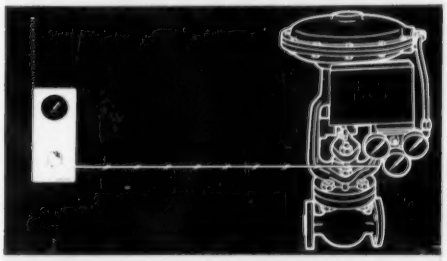


Diaphragm-operated CV-D valve controls the speed of the turbine driving the forced-draft fan. Copes-Vulcan also makes piston-actuated valves. Both types meet pressure standards of 125 to 2500 pounds.

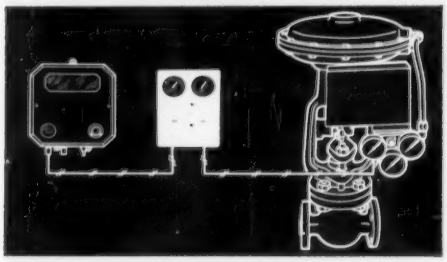
The drive unit with positioner, 4-way valve, power piston and feedback cam controls forced-draft damper. C-V drive units permit remote positioning by automatic or manual pneumatic signals.

C-V NEWS NOTES

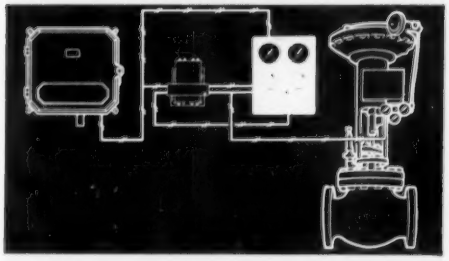
PNEUMATIC CONTROL STATIONS



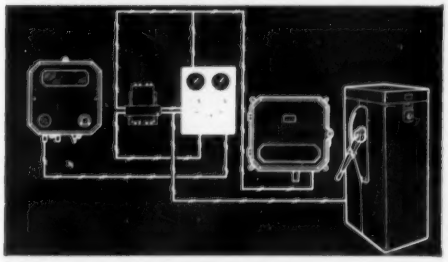
Copes-Vulcan stations offer automatic-to-manual selection without the complication of seal balance. They indicate process-variable, controller and manual loadings. Transfer is "bumpless" without process disturbance. **Shown above: the ML-4 Manual Loading Station.**



AM-4 Selector Station . . . indicates an automatic loading—or originates a manual loading—to the valve, power cylinder or other control element.



AMS-4 Remote Set Station permits manually adjustable set-point loading, or independent manual operation, of the control element.

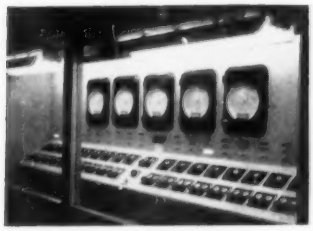


AMBC-4 Cascade Biasing Station, used with pneumatic stacked diaphragm controllers, permits plus-or-minus biasing of a cascaded set-point to the controller.

For details about Copes-Vulcan's complete line of pneumatic control stations, write for Bulletin 1031.

HAGAN NEWSLETTER

Behind the Panel



AIR LIFT IN A BLAST FURNACE?

The 80,000 cfm or so of air supplied to a blast furnace has two functions: it provides combustion air, and it must also partially support the "burden," the mixture of coke, ore and limestone that is being reduced to pig iron. Blast air enters the furnace through a series of nozzles (tuyeres) arranged around the outside of the furnace. Flow through the nozzles is not normally under control. They are simply left wide open. Uneven distribution of air-flow through the tuyeres and upward through the burden can occur and this may result in refractory damage and "rough" furnace operation. Hagan automatic tuyere flow proportioning control systems lick this problem by metering equal amounts of air to each nozzle. The nozzle with the greatest back pressure is opened wide, and each of the others regulated in accordance with the set point. In this way, optimum furnace conditions are maintained with minimum pressure loss. At a recent installation, operators were skeptical, but after a week's trial run on full automatic, they changed their minds and now insist that the furnace be left on automatic at all times. (Item D-1)

FLEXIBILITY--FIRST IN PRINCIPLE, THEN IN PRACTICE

In principle, torque suppression calls for torque in the opposite direction. Because the Hagan Ring Balance instrument operates on the torque established by different pressures, suppression is achieved by simply adding a weight to the ring, instead of changing range tubes as required by manometric instruments. For example, a Ring Balance instrument set to measure as much as 140 inches of level can be easily suppressed to measure a 20 inch full scale linear change anywhere within the 140 inch level. This flexibility of the instrument allowed a field expedient when there was an oxygen flow problem at a steel mill. A Ring Balance instrument measuring oxygen flow to the open hearth furnaces was installed in such a way that when the scarfing mill, which was ahead of the meter, used oxygen, the demand was so great that the flow past the meter reversed itself, flowing towards the scarfing mill. This reversal was doubted by plant personnel, so the Hagan engineer simply added a weight to the ring so that zero flow was registered at mid-chart. Sure enough, the next time oxygen was used by the scarfing mill, the meter registered the predicted reverse flow. (Item D-2)

TOTALIZING RELAYS--SIMPLE WAY TO ADD MULTIPLE FLOWS

An industrial plant with a total of eight boilers wanted to determine the output of each boiler, and also to chart the total amount of steam produced. Steam is produced at 415 psig and 650 F, and the eight boilers generate approximately 800,000 lbs/hr. maximum. Ring Balance meters with pneumatic transmitters are used on all boilers, and on six of them the steam flow signal is also used for feedwater control. The output of the pneumatic transmitters is fed to a steam flow totalizing relay network consisting of seven Hagan Ratio Totalizers. The output of this network is then recorded on a total plant steam flow receiver recorder. Spot checks by plant personnel over the two years the system has been in operation show that the total of the individual boiler meters comes within 1% of the grand total shown by the total plant steam flow recorder. (Item D-3)

HOW TO COLLECT SOYBEAN DUST

A Hagan Aerostatic Dust Collector is proving very successful in an unusual application for mechanical collectors. Soybean dust containing 44% soy meal with a minimum of 13% moisture is being collected at the rate of 1½ tons a day. On days of high humidity, the moisture content skyrockets, and an ordinary mechanical collector would have real plugging problems. However, the Hagan unit has been operating through periods of extremely high humidity, and has shown no sign of plugging. This is because the honeycomb design of the inlet area allows the inlets to nest closely together so that only sloping surfaces are presented to the dust stream. The plant is saving money on maintenance costs, too. The bag-type collector previously used cost $4-5,000 a year to maintain—while the Hagan unit has required no maintenance at all. (Item D-4)

HAGAN CHEMICALS & CONTROLS, INC.

Hagan Building, Room 703, Pittsburgh 30, Pennsylvania
In Canada: Hagan Corporation (Canada) Limited, Toronto
European Division: Via Flumendosa No. 13, Milano, Italy

If you would like more information on any of the above items, check the appropriate box below.

☐ Item D-1 ☐ Item D-2 ☐ Item D-3 ☐ Item D-4

You Get

EFFICIENT BURNING

With Valley Camp Special Spreader Stoker Coal

Efficient Burning Means Lower Steam Costs.

Ask for special spreader stoker coal.

This quality coal is from our Elm Grove Mine. It is thoroughly cleaned, carefully sized and thermally dried . . . ideal for modern stoker equipment.

THE VALLEY CAMP COAL COMPANY

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bends like this are easy with...

Republic ELECTRUNITE Boiler Tubing

because uniform ductility is built-in

Uniform ductility of ELECTRUNITE® made a big difference at the power plant installation of Toms River-Cincinnati Chemical Corporation, Toms River, New Jersey.

This C-E Boiler, Type VU-50, engineered and erected by Combustion Engineering, Inc., New York City, was designed for maximum operation of 157,000 lbs. per hour at 650°F., with 600 lbs. psi design pressure. Fifty-one tons of Republic ELECTRUNITE Boiler Tubing were used in this unit.

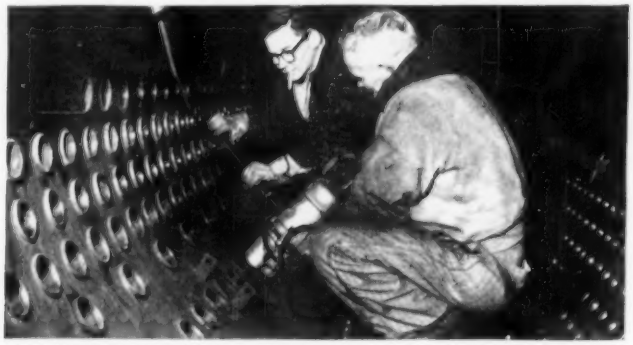
Here, Republic ELECTRUNITE Boiler Tubing met the curvature of the boiler design in a severe test of uniform ductility. Bends were smooth and uniform, fitted easily into the boiler head drum holes. Results: Savings in installation time and costs.

ELECTRUNITE is made of highest quality flat-rolled open-hearth steel produced in Republic's own mills, carefully controlled every step of the way. Full normalizing, uniform wall thickness and diameter, and uniform ductility assure easy workability and in service dependability.

ELECTRUNITE is produced by the exclusive process that ELECTRically-UNITEs the tube under pressure without additional foreign or extra metal. This process is universally accepted by leading technical authorities, code societies, boiler and heat exchanger manufacturers, Federal and State committees.

To learn more about ELECTRUNITE for boiler, heat exchanger, condenser, or evaporator applications, call your Republic representative. Or, write direct.

FARROWTEST®—QUALITY YOU CAN MEASURE. Not a laboratory theory, not a mere inspection tool, but an exclusive production test that detects and rejects tubing containing defects of critical size. FARROWTEST is offered as an alternative to other less positive tests in accordance with table below, at no extra cost.

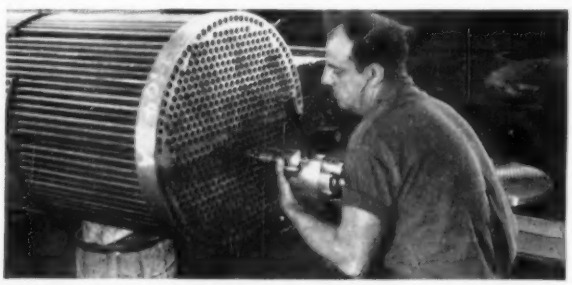


QUALITY YOU CAN SEE! Republic ELECTRUNITE Boiler Tubing uniform ductility pays off in fit-right installations. Full normalizing and true concentricity assure easier roller expanding. Trouble-free service on the inside is a big factor in savings in installation time and costs.

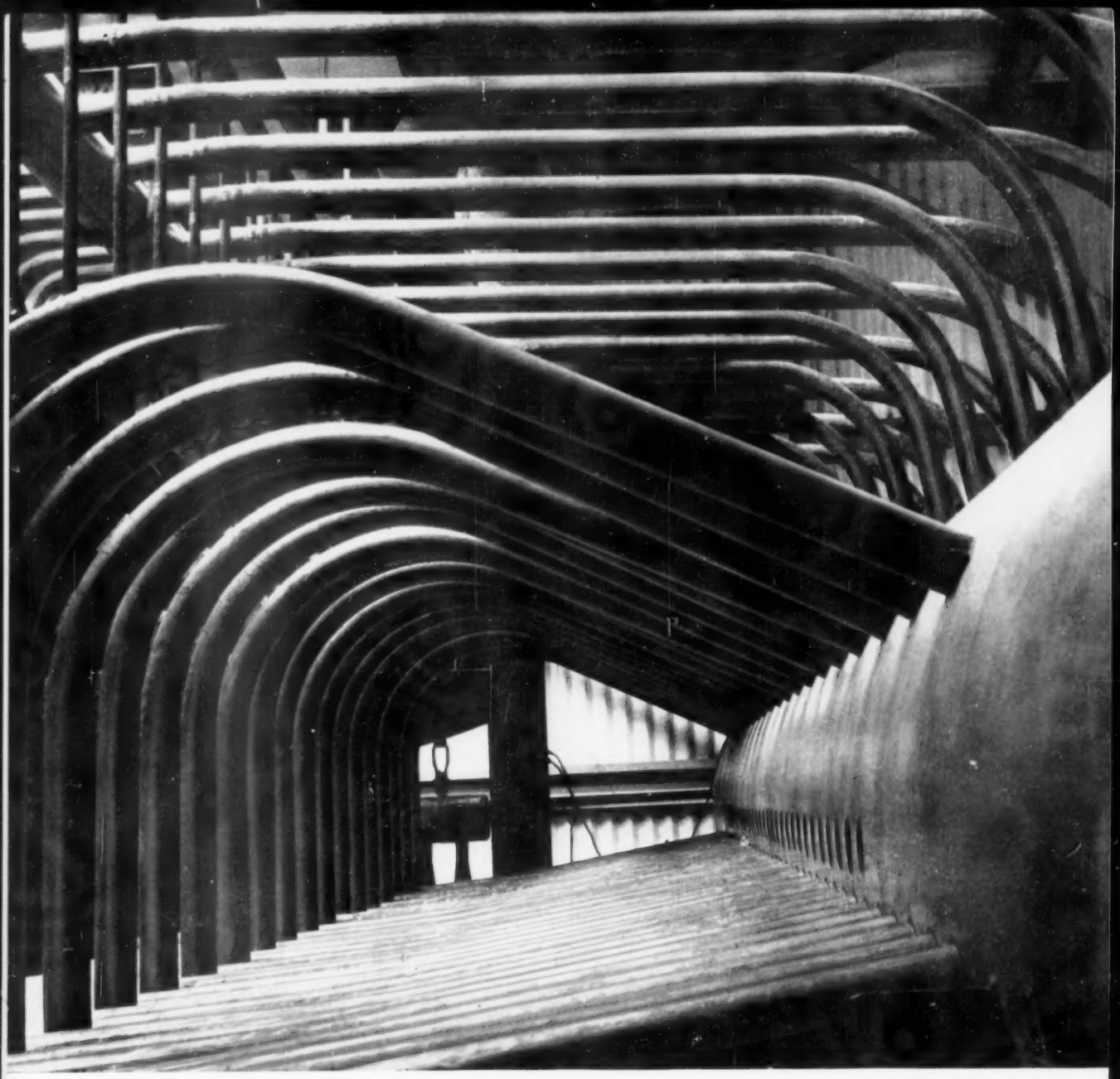
FARROWTEST REJECT TABLE

Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006″	.0025 sq. inches
18	.006″	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.



GOT A WATER PROBLEM? Republic ELECTRUNITE Stainless Steel Heat Exchanger Tubing resists corrosion and provides long trouble-free service for main surface condensers in utility power plants where water is used directly from natural sources. Call your Republic representative, or write direct.



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Please send additional information on the following products:

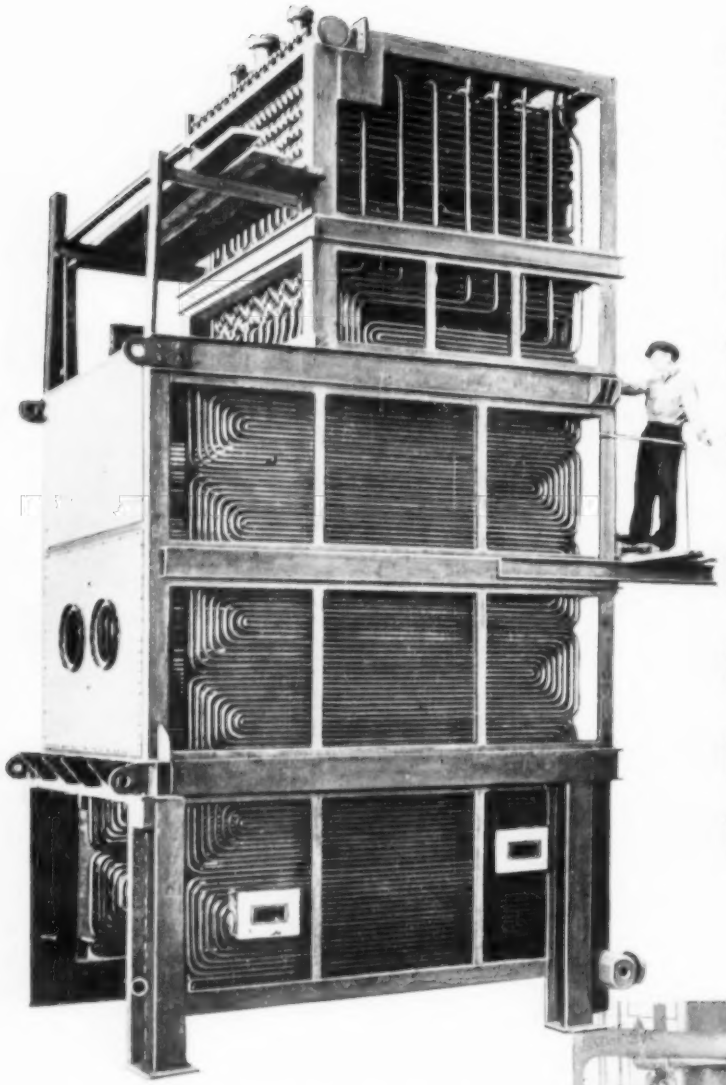
☐ Republic ELECTRUNITE Boiler Tubes
☐ Republic ELECTRUNITE Heat Exchanger Tubes
☐ Carbon, or ☐ Stainless ☐ FARROWTEST Brochure

Name_____ Title_____

Firm_____

Address_____

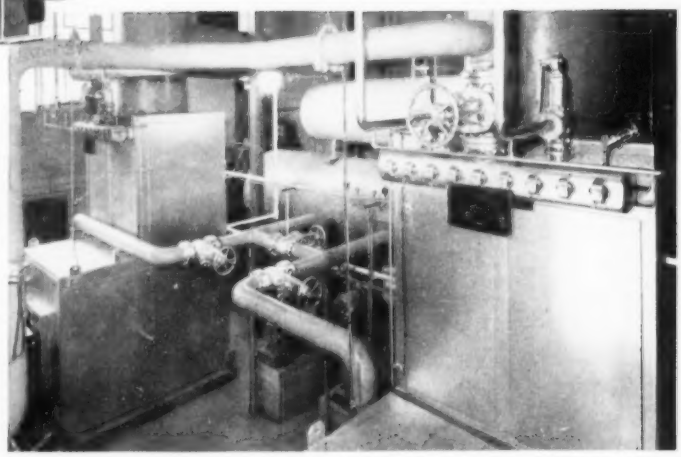
City_____ Zone____ State_____



In new plants large and small...

The C-E high temperature water boiler offers savings of 10 to 20%

Shop assembly view showing steel frame and pressure parts for 25 million Btu unit prior to installation of refractory, insulation block, and welded gastight casing.



Compactness of C-E HCC Boilers is demonstrated in this view of two 10 million Btu units installed at a new Michigan high school.

COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

C-190

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT. NUCLEAR REACTORS. PAPER MILL EQUIPMENT. PULVERIZERS. FLASH DRYING SYSTEMS. PRESSURE VESSELS. SOIL PIPE

The list at right points up the versatility and widespread acceptance of Combustion Engineering's HCC boiler. For industrials, schools, institutional use, military bases—wherever there is extensive space to be heated—C-E high temperature water has a place.

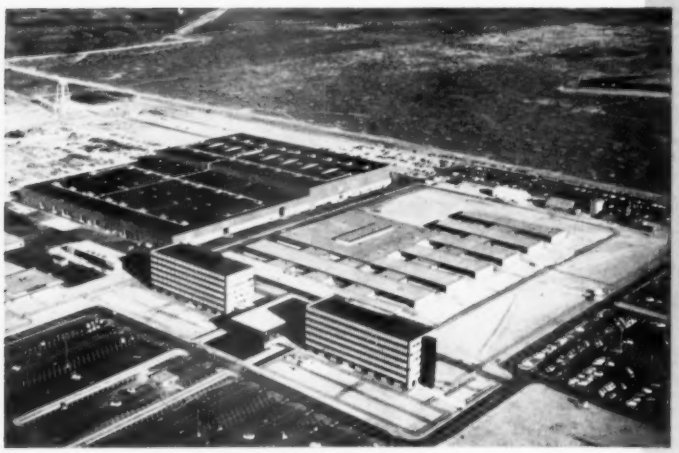
Featuring the same principle applied by Combustion in many of its large utility boilers, the C-E LaMont Controlled Circulation Hot Water Boiler offers a compact and effective arrangement of heating surfaces. This design gives precision temperature control, and, dependent upon local conditions, the HCC can save 10 to 20 per cent in maintenance and operating costs—a significant factor when considering a heat source.

Available in a wide capacity range—from 10 to 300-million Btu's—these boilers operate at water pressures up to 500 psi and temperatures to 470 F or higher. The smaller capacity HCC's are completely shop-assembled, while the intermediate and large units are shipped in varying stages of assembly. This C-E practice greatly reduces erection costs.

If you are in the market for boilers, either for space heating or process requirements, it may prove greatly to your advantage to investigate C-E high temperature water as your heat source.

Because individual needs vary, *both* steam and hot water have their applications. Combustion Engineering can furnish either, and our engineers are exceptionally qualified to discuss *impartially* with you or your consultants the method most suitable for your situation.

Write for further details on Combustion Engineering's High Temperature Water Boilers.



One of the many large plants using C-E High Temperature Water Boilers is Convair-Astronautics Division of the General Dynamics Corporation. Installed at this new $40-million center for Atlas Intercontinental Ballistic Missile research, development, manufacture, and primary testing are two 30-million Btu HCC Boilers.

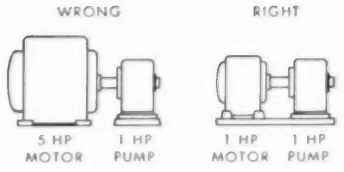
Representative list of C-E HCC Boilers in service, under construction, or on order

	No. of Units	Normal Output ea.—Btu/Hr. (millions)	How Fired
A. E. Smith High School Riverview, Michigan	2	10	Oil
J. Bishop & Co. Malvern, Pa.	1	12	Oil
Colorado State College Greeley, Colo.	1	60	Oil— Nat. Gas
Cross Company, The Frazer, Michigan	2	12	Nat. Gas— Oil—
Defense Construction Ltd. Camp Gagetown, N. B., Canada	3	70	Pulv. Coal— Gas
Erie Mining Company Aurora, Minn.	2	65	Stokers— Oil or Gas
Convair Astronautics Div. General Dynamics Corp. San Diego, Calif.	2	30	Oil— Nat. Gas
General Motors Overseas Santos, Brazil	1	12	Oil
Hillcrest Medical Center Tulsa, Oklahoma	1	30	Nat. Gas
Marquardt Aircraft Co. Ogden, Utah	2	12	Oil— Nat. Gas
Michigan State University Oakland, Michigan	1	12	Oil— Nat. Gas
New Florida State Prison Raiford, Florida	2	30	Oil— Nat. Gas
North Carolina Wesleyan College Rocky Mount, N. C.	2	18	Oil— Nat. Gas
U. S. Air Force Academy Colorado Springs, Colorado	3 2	100 30	Oil— Nat. Gas
U. S. AIR FORCE: Clinton County Air Force Base Wilmington, Ohio	1	16	Stoker
Dover Air Force Base Dover, Delaware	3	50	Oil— (Fut. Coal)
Forbes Air Force Base Topeka, Kansas	3	42	Oil— Nat. Gas (Fut. Coal)
Grand Forks Air Force Base Grand Forks, North Dakota	2	25	Stokers— Oil
McGuire Air Force Base Wrightstown, N. J.	4	50	Stokers
Minot Air Force Base Minot, North Dakota	2	25	Stokers— Oil
Plattsburgh Air Force Base Plattsburgh, N. Y.	2	50	Oil
Portsmouth Air Force Base Portsmouth, N. H.	2	110	Oil— Nat. Gas (Fut. Coal)
Wright-Patterson Air Force Base Dayton, Ohio	1	30	Stoker
Wuthsmith Air Force Base Osceola, Michigan	2	25	Stokers
Air Force Base Torejon, Spain	3	43	Oil
U. S. Navy Auxiliary Air Station Fallon, Nevada	2	15	Oil

Tips on evaluating Electrical

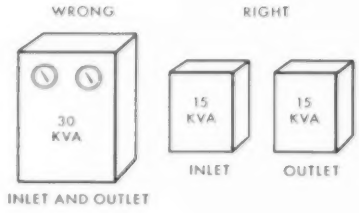
Matched Electrical Sets

You wouldn't use a 5 h.p. motor to run a pump that required only one h.p. Similarly, electrical sets should be *matched* to the requirements of the specific job. Electrical sets should be sized according to gas conditions, dust conditions, and other operating characteristics, and in accord with manufacturers' past experience on similar installations. *Don't be misled by high KVA ratings on the electrical sets.* The precipitator will only absorb a certain amount of power and the sets should be sized accordingly. A large excess of installed power, which will never be used, means inefficient use of the equipment.



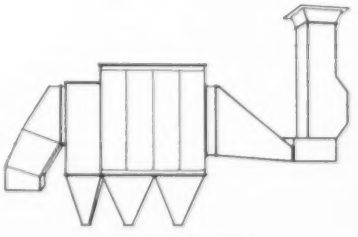
Varied Electrical Conditions

Electrical conditions in a precipitator can vary widely at different parts of the precipitator. For instance, a high voltage, low current condition usually prevails at the inlet where the dust load is high, as compared to a lower voltage higher current condition at the outlet. Consequently, it is good design (and a necessity for high efficiency) to furnish several electrical sections in series, with energization from separate electrical sets so that each section can be adjusted to best suit the conditions.



Gas Distribution

Remember that gas distribution, gas baffling, and provision against hopper sweeping all have a large influence on collection efficiency. The gas flow system should be analyzed as closely as possible, both in the precipitator and in the associated ductwork. If in doubt, have a three-dimensional gas flow study made. Two-dimensional gas flow studies *are not as accurate* and may lead to erroneous conclusions.



RESEARCH

RESEARCH-COTTRELL, INC. Main Office and Plant: Bound Brook, New Jersey

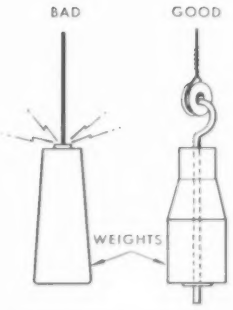
RC-181

Precipitators

Some helpful hints to aid in selecting a properly designed unit

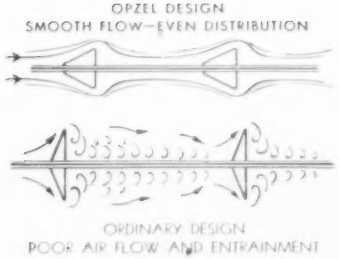
Rapping Intensity

Rappers should have easy means to vary the intensity of the blow to suit variations in operating conditions. A pre-set intensity setting cannot possibly give proper rapping over the normal range of operation. If too soft, build-up will occur which will disturb electrical conditions. If too hard, there will be reentrainment. Means of intensity adjustment are necessary to avoid drop-off of precipitator efficiency as conditions change.



Corona Discharge

It is a relatively easy matter to obtain a corona discharge in an electrostatic precipitator. Many types of discharge electrodes have been used over the past forty years, including ribbons, squares, twisted squares, star shaped sections, coiled wires, wires with prongs and projections, most of which give entirely adequate corona conditions. Final choice then gets down to mechanical factors such as strength of wire, method of support to avoid stress points, and ease of handling. There are many claims made for various types of wires but after investigating and testing hundreds of different kinds, we find a straight round wire about .1″ diameter to be best.



Baffle Design

Careful attention to the design of baffles on the collecting plates is most important. Small amounts of reentrainment mean tremendous differences in over-all collection efficiencies. It is seen that the "quality" of the collecting surface is far more important than quantity — quantity (sq. ft. of surface or treatment time) in itself is not a criterion of performance.

-COTTRELL

Representatives in all major cities of U.S. and Canada

DAMPNEY COATINGS LIVE WITH IT!

True measure of a high-heat coating's worth is *continuous operation at rated temperature.* Yet many so-called "heat-resistant" coatings take only occasional peaks — fail rapidly in 'round-the-clock service.

Dampney coatings are rated always for day in, day out operation at maximum temperatures. Hold them to it, if schedules call for steady heat, or let them fluctuate to ambient and back. Either way, Dampney silicones and ceramics give you full protection — with plenty in reserve.

Most important, Dampney coatings are selected to meet specific conditions of operation, temperature and corrosive environment. Thus they establish a lasting foundation easily maintained and permanently ending time-consuming and costly surface preparation.

Repeat orders — from a typical customer, 26 in 12 months for enough material to protect 1,929,000 square feet of steel — is the best evidence we have that when industry wants honest high-temperature coatings, it remembers Dampney silicones and ceramics, identified by the two trade names, DAMPNEY and THUR-MA-LOX.

We suggest you do likewise when you want real protection — resistant to 1000° F., to atmospheric corrosion, and to weather exposure — for these industrial hot spots . . .

stacks and breechings	•	turbine interiors
steam lines	•	precipitators
kilns	•	coke ovens
forced and induced draft fans	•	incinerators
heat-treating furnaces	•	pulverizers
autoclaves and retorts	•	blast and open hearth furnaces

Remember, too, the first Dampney trade name and product, known and used today the world around, APEXIOR NUMBER 1 for boiler interiors. For all hot metal, wet or dry, the best protection available is made and marketed by

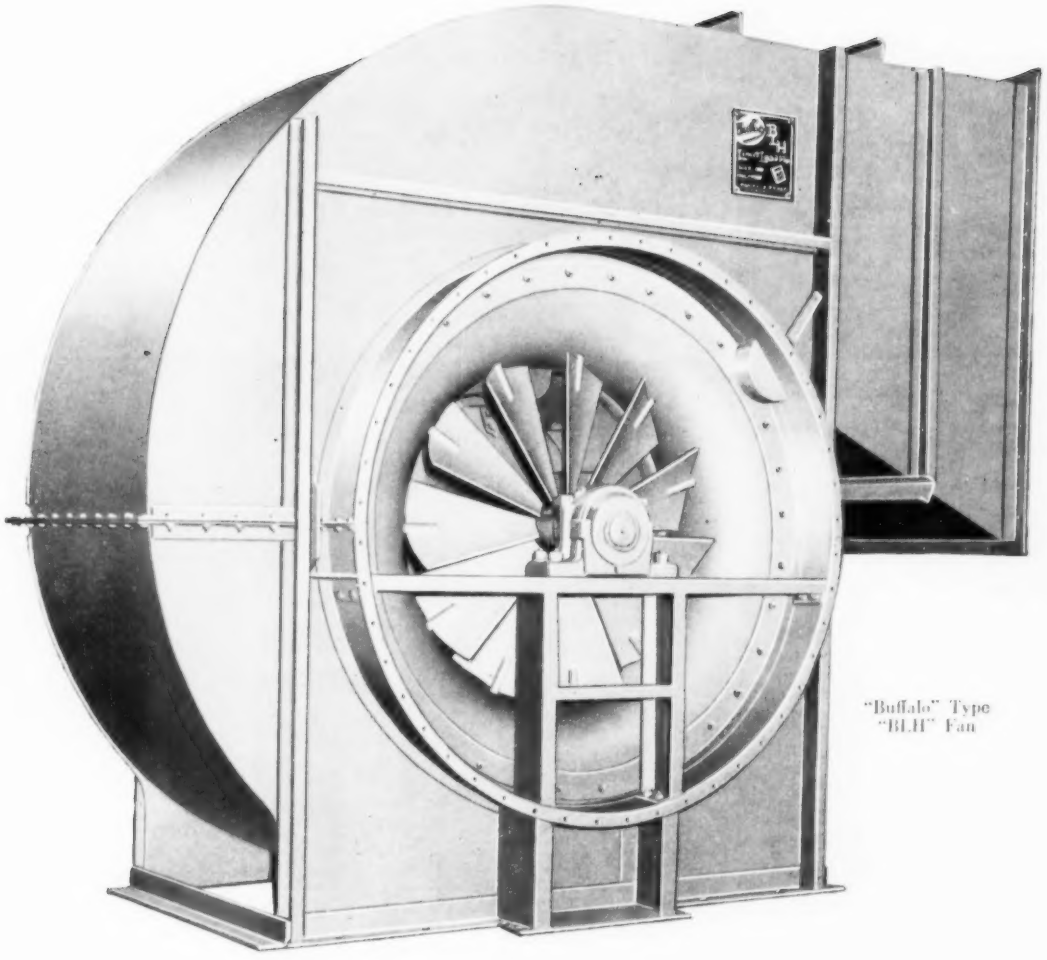
MAINTENANCE FOR METAL

THE DAMPNEY COMPANY

HYDE PARK, BOSTON 36, MASSACHUSETTS

Coatings for all temperatures to high heat — all corrosive environments.

207



"Buffalo" Type "BLH" Fan

HIGH EFFICIENCY OVER BROAD OPERATING RANGE PROBABLY YOUR BEST CHOICE FOR M. D. FANS

Does your mechanical draft installation require a fan that delivers peak-efficiency performance over a broad range? A fan that will give you this with the greatest possible long-range economy?

Then the "Buffalo" Type "BLH" is the fan you're looking for.

The "Buffalo" Type "BLH" Fan maintains a high mechanical efficiency over a very broad operating range with a peak efficiency of 86%. And it does this smoothly, quietly and most economically because of a number of important "Buffalo" design factors:

• Streamlined housing is uniquely engineered to provide smoothest air flow, highest possible static conversion and excellent pressure distribution at fan outlet.

• Minimizing turbulence are the smooth inlet bell, directional inlet vanes (standard, matching variable inlet vanes are optional) backward-curved blades, rotor flange curved to match inlet bell and the gradually divergent outlet. These features also result in extremely efficient performance and outstandingly stable operation from free delivery to shutoff.

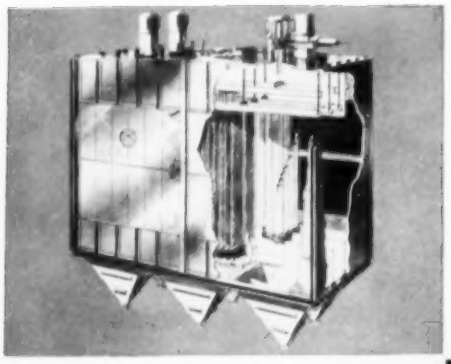
• The 82 year old "Buffalo" reputation for rugged, dependable construction insures long, maintenance-free life.

If you're looking for this kind of efficiency and economy in a mechanical draft fan, call your nearby "Buffalo" engineering representative. Or write us for Bulletin FD-905.

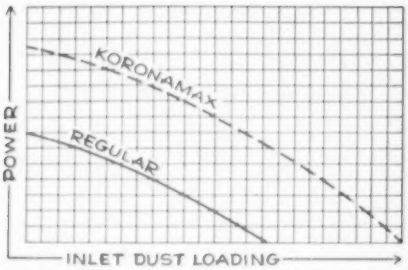
BUFFALO FORGE COMPANY
Buffalo, N. Y.

Buffalo Pumps Division • Buffalo, N. Y.
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

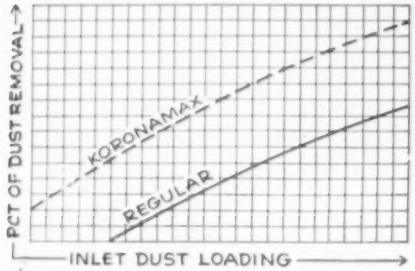
VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING • FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING



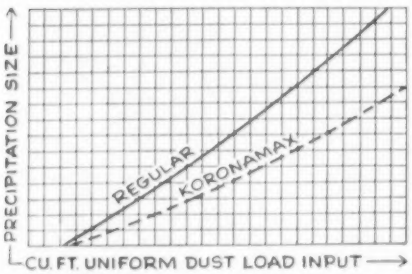
Another Koppers Exclusive in ELECTROSTATIC PRECIPITATION



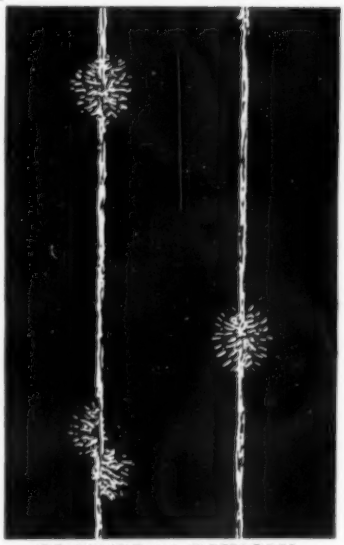
INCREASED POWER—The evenly spaced discharge points of "Koronamax" Electrodes reduce the arc-over tendency and permit increasing power input.



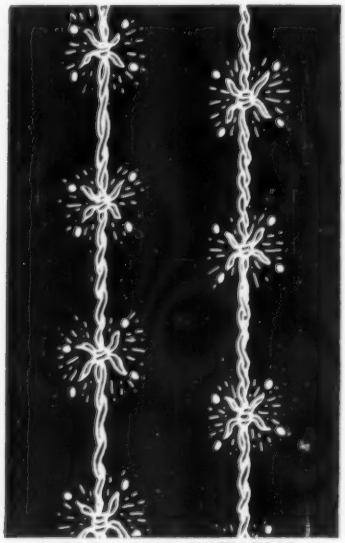
HIGHER EFFICIENCY—Replacement of regular electrodes with "Koronamax" Electrodes allows higher power input — greatly increased efficiency.



SMALLER SIZE—In new installations desired efficiency may be obtained with smaller unit when "Koronamax" Electrodes are used.



CONVENTIONAL ELECTRODES



"KORONAMAX" ELECTRODES

"KORONAMAX" ELECTRODES increase efficiency and capacity of electrostatic precipitators

"Koronamax" Electrodes developed by Koppers are now in service in several different applications and their *controlled* corona discharge has resulted in greatly increased capacity and efficiency. This unique type of precipitator electrode may solve *your* gas cleaning problem.

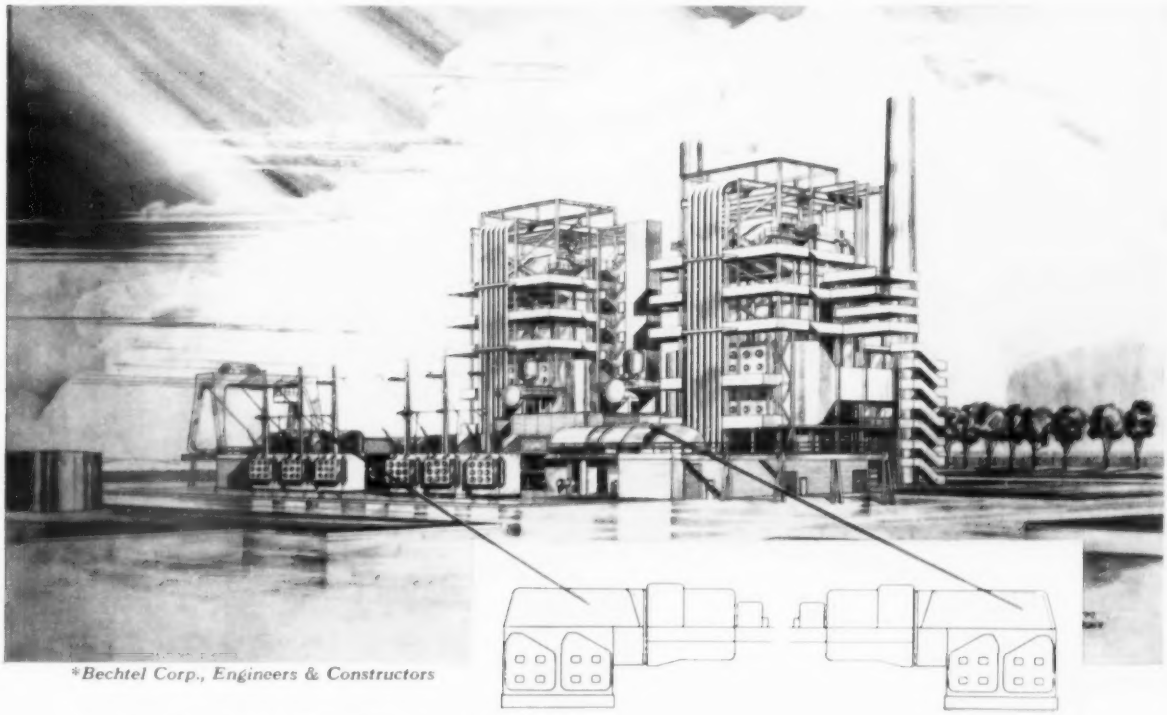
Koppers' experience, constant research and extensive field testing have led to this important advance in precipitator design. Check with Koppers to see if "Koronamax" Electrodes can help you get top precipitator efficiency. For more information, write: KOPPERS COMPANY, INC., 7105 Scott Street, Baltimore 3, Md.

KOPPERS

ELECTROSTATIC PRECIPITATORS

Engineered Products Sold with *Service*

For Southern California Edison Company's new Huntington Beach Steam Station*...



*Bechtel Corp., Engineers & Constructors

Ingersoll-Rand

axial-inlet condensers will serve each 200 MW unit

Designed for an eventual four units, the first two units of the new Huntington Beach Steam Station are now under construction. Turbines are cross-compound axial exhaust, 2400 psig., 1050 /1000 , 3600 /1800 rpm. As indicated above in the artist's rendering, these units will be served by axial-inlet condensers, specially designed for this installation by Ingersoll-Rand. These I-R condensers are 2-pass units, each with 110,000 sq ft of surface.

In addition to the surface condensers, Ingersoll-Rand is furnishing the following associated equipment:

5 boiler-feed pumps rated 2020 gpm at 6400 ft TDH.

4 vertical condensate pumps, 3-stage, rated 2500 gpm at 350 ft TDH.

5 condensate booster pumps, rated 1851 gpm at 1970 ft TDH.

4 vertical condenser circulating pumps, rated 44,000 gpm at 35 ft TDH. The columns and discharge head sections are lined with Fiberglas.

2 steam-jet ejector units, 2-stage, single-element with surface-type inter and after condensers.

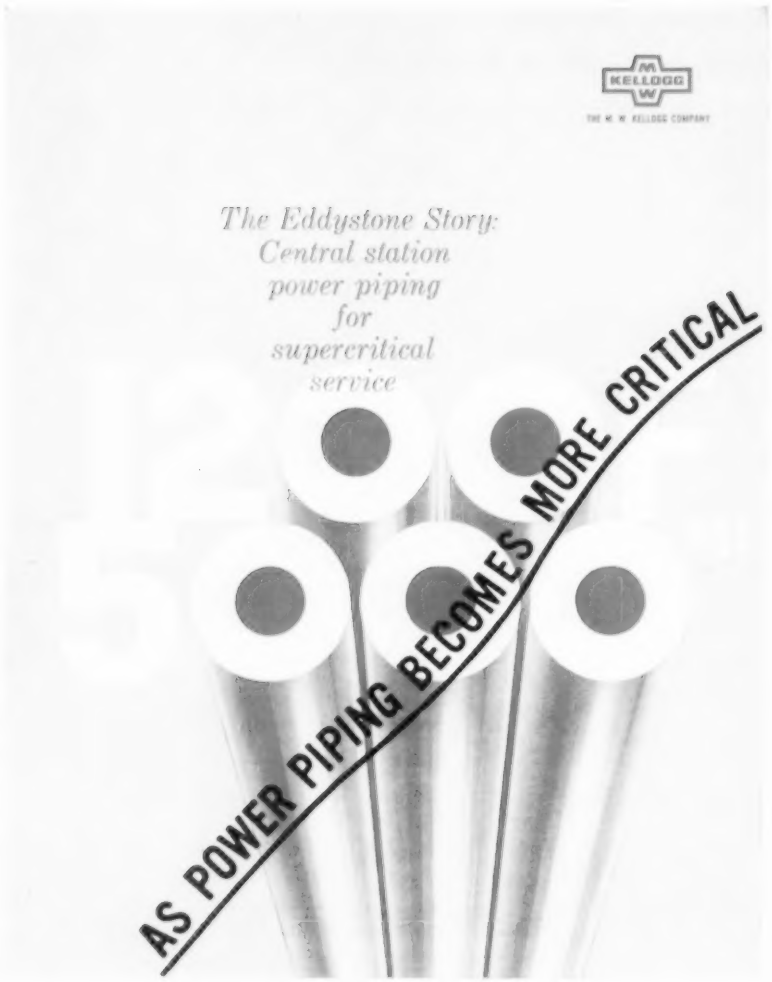
2 horizontal reciprocating vacuum pumps each driven by a 100 hp electric motor.

This installation is another dramatic example of Ingersoll-Rand's ability to meet the requirements of the modern steam plant... with advanced design surface condensers, pumps and associated equipment. Your I-R engineer will be glad to help you determine the equipment best suited to *your* requirements.

Ingersoll-Rand

4-874 11 Broadway, New York 4, N. Y.

THERE'S NO SUBSTITUTE FOR EXPERIENCE IN ENGINEERED PRODUCTS



M. W. Kellogg's

Complete

Power Piping

Service

Keeps Pace

The services performed on one major assignment—the supercritical power piping for Eddystone Station, Unit No. 1—are evidence of The M. W. Kellogg Company's capability to solve the many critical problems encountered with power piping in the modern steam-electric plant.

Kellogg's services for Philadelphia Electric Company during the course of this project have included metallurgical research, flexibility analysis, material specifications, K-welding* and testing during fabrication in Kellogg's Jersey City shop and during field erection.

Some idea of the magnitude and complexity of Kellogg's responsibilities at Eddystone, and how problems were solved, may be obtained from the new 12-page Kellogg booklet, "The Eddystone Story", shown above. Copies will be sent promptly on requests from consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

- **Metallurgical Research**
- **Flexibility Analysis**
- **Material Specifications**
- **Shop Fabrication**
- **Field Erection**

Kellogg welcomes the opportunity to discuss any or all of its complete power piping facilities with representatives of the industry.

Fabricated Products Sales Division

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

A SUBSIDIARY OF PULLMAN INCORPORATED

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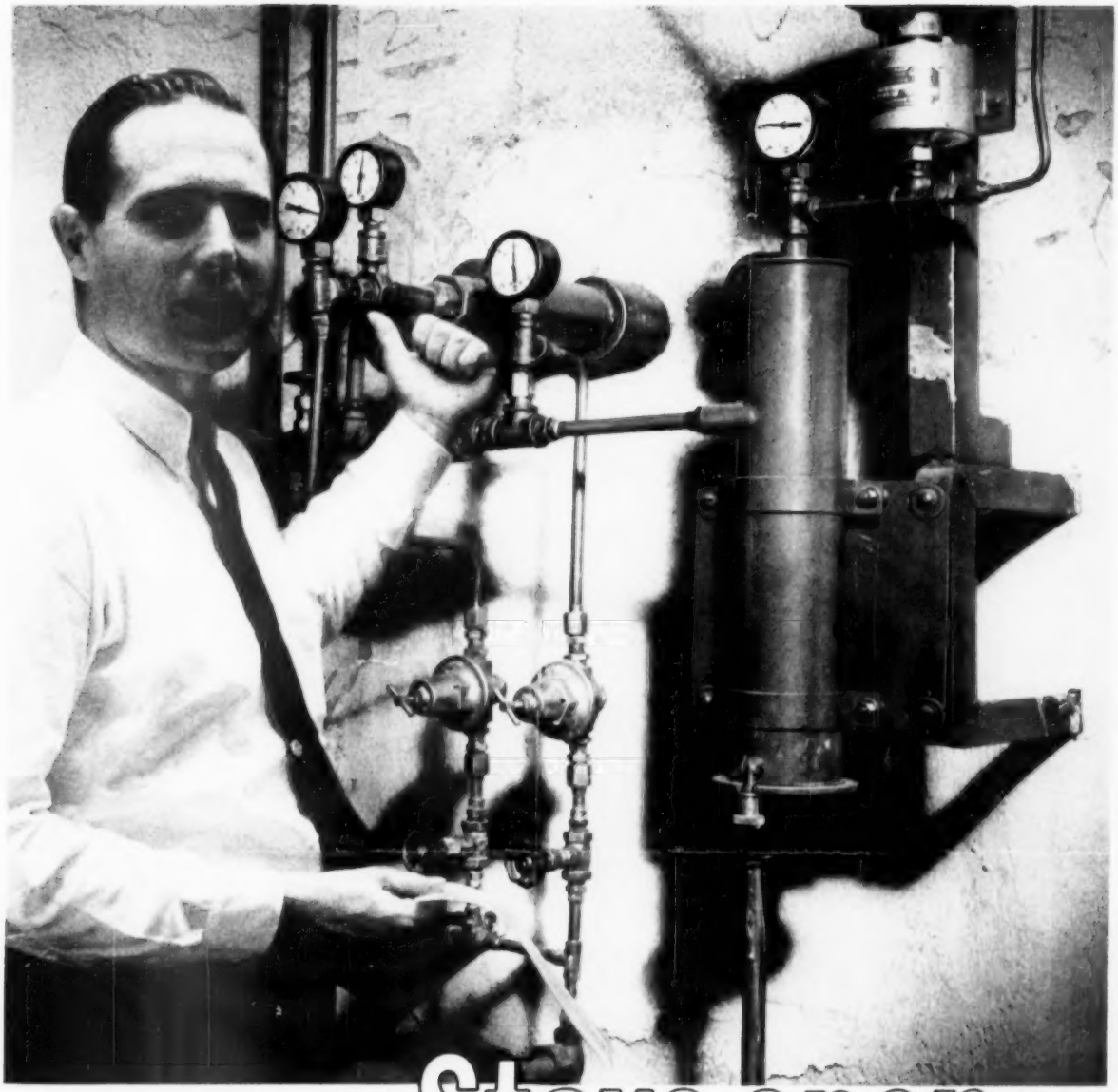
POWER PIPING—THE VITAL LINK

** Registered Trademark of The M. W. Kellogg Company*



This Reverse Jet Probe Stays open

The most critical component of any O_2 analyzing system is its sampling equipment. Unless it gives a continuous, reliable sample, the system can't function satisfactorily.

The L&N O_2 Analyzing System gives you the Reverse Jet Probe and Steam Sampler shown above. A high velocity water jet continuously functions to keep the probe clear. The Steam Sampler cleans all dirt and acid from the sample and pressurizes it for rapid transmission (45 fps). Performance is reliable, requiring only reasonable maintenance.

Components of the complete L&N O_2 Sampling and Analyzing System include:

1. *Reverse Jet Probe and Steam Sampler*
2. *Sample Averaging Panel (for multi-probe installations)*
3. *Magnetic O_2 Analyzer*
4. *Speedomax® Electronic Recorder*

For further information, contact your nearby L&N Field Engineer, or write for our O_2 Analyzing Systems Folder to 4972 Stenton Ave., Philadelphia 44, Pa.

O_2 Analyzing System engineered to power plant standards by **LEEDS & NORTHRUP** Instruments, Automatic Controls • Furnaces

Background: El Segundo Station of Southern California Edison Company. Foreground: Installation of Cooper-Bessemer Soot Blowing Compressors at El Segundo.

Dann Goodson, *Manager Motor-Driven Compressor Sales, The Cooper-Bessemer Corporation, explains...*

How soot blowing with air increases power plant efficiency

POWER PLANTS are switching from steam to compressed air for cleaning of furnaces and tube banks because they can *reduce costs*. The new way, with Cooper-Bessemer compressors, has these important advantages:

1. **Pressure is always adequate to do clean, thorough job.**
2. **Better programming with air... gets better cleaning results for higher boiler efficiency.**
3. **Lower initial cost, lower operating cost, and hence lower cost for blowing medium... less waste.**
4. **No quenching action on hot alloy tubes or pressure vessels.**
5. **Less maintenance of blower equipment due to erosion, corrosion, packing wear.**
6. **Improved housekeeping... no steam or condensate leakage.**
7. **Greater over-all economy of blowing medium on evaluated basis.**
8. **Eliminates condensate makeup required when blowing with steam.**

You can find out more about this by writing for a copy of the article reprint, "Steam or Air: Which costs more for boiler cleaning?" We would be glad to help you in planning your compressor facilities for soot blowing... or other power plant uses. Call the office near you.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester
Chicago • Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans
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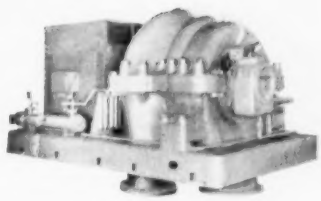
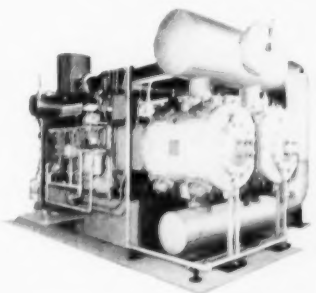


Direct motor-driven multi-stage centrifugal compressor. Sizes of 3000 cfm free air and up.

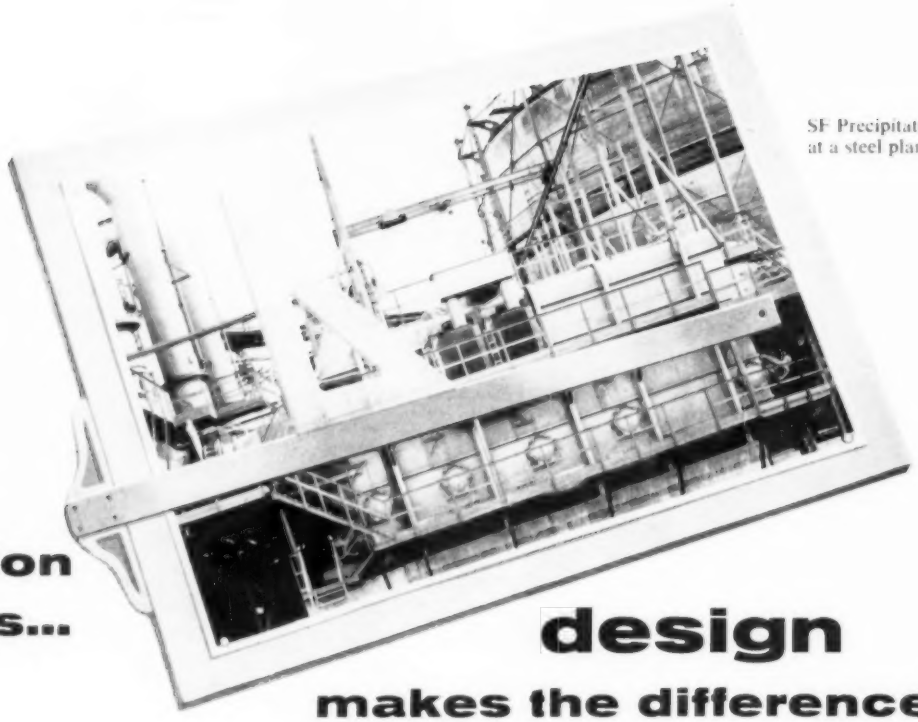


Multi-stage reciprocating compressor. Sizes up to 30,000 cfm free air.

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS • DIESEL • GAS DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL,
ENGINE OR MOTOR DRIVEN

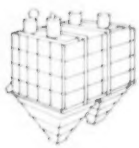


SF Precipitator at a steel plant.

In Dust Collection Systems... design makes the difference

Higher efficiency of Buell "SF" Electric Precipitators is the result of exclusive engineering features. For example, Buell's *Spiralectrodes* emit 50% to 100% more electrons than other types . . . and *maintain* their efficiency. Positive gas flow control through adjustable baffles prevents scouring and eddying. And Buell's Unique Continuous Cycle Rapping practically eliminates "puffing".

BUELL CYCLONES



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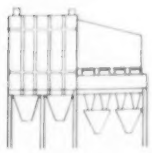

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Editorial

The Language of an Industry

Recently the *San Francisco Chronicle* ran an editorial on "Ruggedizing the Language." It was a clever and piercing thrust at the public relations expert whose announced specialty is an ability to inform the layman in layman's language of the wonders of science and the workings of the latest engineering development. The particular news release which prompted the *Chronicle* editorial was one on the ACRE—Automatic Checkout and Readiness Equipment. A choice paragraph the *Chronicle* quoted reads "Under control of a stored program an appropriate stimulus generator is selected and adjusted. The stimulus, directed to the proper missile umbilical wire, elicits a response from the missile subsystem. This response returns to ACRE where it is digitized and evaluated on the basis of stored test limits." Says the *Chronicle*, "As far as we are concerned it (meaning this as an example of the American layman's language) has snapped the umbilical wire." We must agree.

In a larger sense, though, the umbilical wire, if ever there was one, between layman and the engineering field has long been snapped. The contention that any engineering accomplishment or development can be explained in layman's language and in sentences that march along in cadence with some mystical readership formula has always flabbergasted us. No such string of laymen's language can bridge the years of experience that go into making a man conversant with the specialized phases of engineering. This is one of the main reasons for the existence of the technical press.

In fact as a publication we contact a percentage of our readership monthly and our current contact letter states this: "For years COMBUSTION has followed a policy of concentrating on steam generation in the belief that its readers want comprehensive, authoritative articles on this subject. To effect this policy the magazine has not been sparing of space allotted to individual articles nor has it shied away from the use of mathematical equations and the technical language of the industry." So far the overwhelming majority of our readers so contacted bear us out. We are reporting to an adult audience on an industry of stature, about accomplishments of note and the primer treatment is out of character.

This paper discusses modern power station boiler troubles associated with oil firing, including the corrosion and blockage of high-and-low temperature surfaces swept by the flue gases. An account is given of experiences with several additives to relieve troubles of this kind.

By W. D. JARVIS†

Central Electricity Generating Board

The Selection and Use of Additives in Oil-fired Boilers*

THE use of heavy fuel oil in modern oil-fired boilers has been the cause of a loss of boiler availability due to the external fouling and corrosion of the high- and low-temperature heat exchange surfaces. The problem has become more acute in recent years probably because of boiler design pressures and temperatures.

Troubles which have occurred include slagging in the combustion chamber, the formation of bonded deposits on the high-temperature surfaces, accompanied by the corrosion of uncooled, superheater hangers and spacers and the corrosion and blockage of airheaters and other ancillary equipment operating at lower temperatures.

In this country oil-fired boilers have not experienced troubles associated with bonded deposits on the superheater surfaces, but the possibility of its occurrence should not be overlooked. On the other hand, oil-fired boilers operated by the Central Electricity Generating Board have experienced serious airheater blockage and corrosion shortly after being put into service.

Consequently consideration has been given to the use of materials which, when added to the flue gases, would serve to alleviate these troubles.

The Problem

Heavy fuel oils, used for steam raising purposes in industrial power stations, are produced from crude oil by blending the heavy liquid residues which remain after the removal of the valuable oil fractions, with heavy distillate oil. The characteristics of a typical heavy fuel oil, including an analysis of the oil ash, is given in Table I.

The effect of the various mineral constituents on boiler fouling and corrosion has been the subject of many investigations and a brief review of some of the work will be helpful when consideration is given to alleviation.

Analyses of laboratory prepared ash show that the major constituents are vanadium pentoxide, sodium oxide and sulfuric anhydride probably present in the oil as vanadium, sodium salts and sulfur.

During combustion vanadium is oxidized to vanadium pentoxide and sulfur to sulfur dioxide and sulfur trioxide. Vanadium pentoxide and sodium salts volatilize at furnace temperatures and condense subsequently on the cooler metal surfaces. By combination with sulfur trioxide deposits are formed containing complex vanadium compounds and alkali sulfates which have a relatively low fusion point (*c.* 2100 F) (1).[1] The deposits vary in appearance according to their chemical composition, from a lightly sintered powder to a hard, bonded material which cannot be removed from the heating surfaces by sootblowing. Blockage of the gas passages may occur accompanied by slagging on combustion chamber walls.

A typical analysis of a troublesome superheater deposit is shown in Table II.

* Paper published with the permission of the *Journal of The Institute of Fuel*, 18 Devonshire St., Portland Place, London, W1, from their Journal of November, 1958.

† Head of Fuels and Combustion Section.

[1] Numbers in parentheses refer to List of References at the end of the article.

TABLE I ANALYSIS OF HEAVY FUEL OIL

Specific gravity 60 F/60 F	0.983
Viscosity at 100 F (Redwood No. 1)	6000 sec
Calorific value	18,300 Btu/lb

Ultimate Analysis

Constituent	Percentage by Weight
Carbon	85.20
Hydrogen	10.90
Sulfur	3.60
Nitrogen	0.20
Ash	0.06

Mineral Constituents of Laboratory Prepared Ash

Constituent	Percentage by Weight	Ppm by Weight in Oil
Silica, SiO_2	1	8
Alumina, Al_2O_3	2	14
Ferric oxide, Fe_2O_3	2	13
Vanadium pentoxide, V_2O_5	26	155
Nickel oxide, NiO	5	31
Calcium oxide, CaO	2	11
Magnesium oxide, MgO	2	9
Sodium oxide, Na_2O	24	145
Sulfur trioxide, SO_3	34	207
Minor constituents	2	

TABLE 2 ANALYSIS OF A SUPERHEATER DEPOSIT

Constituent	Percentage by Weight
Silica, SiO_2	2.8
Alumina, Al_2O_3	2.1
Iron oxide, Fe_2O_3	4.8
Calcium oxide, CaO	7.8
Magnesium oxide, MgO	1.8
Vanadium oxide, V_2O_5	8.6
Alkalis, Na_2O	24.3
Sulfates, SO_3	43.8

TABLE 3 PROBABLE FLUE GAS COMPOSITION

Constituent	Lb Mol 100 Lb Oil	13 Per Cent CO_2 (Dry) Per Cent Weight	Per Cent Volume
Carbon dioxide	7.10	17.9	11.8
Water vapor	5.45	5.4	8.8
Sulfur dioxide	0.11	0.4	0.2
Nitrogen	37.30	59.2	61.9
Excess air	Nil	17.1	17.3

The sodium content itself has considerable influence on the formation of troublesome deposits. Trials with gas turbines (2) showed that fouling could be alleviated by reducing the sodium content of the oil from 100 to 10 ppm. Serious superheater fouling occurred in an oil-fired boiler at Piratininga within several days when the sodium content of the oil had increased.

A problem associated with the formation of deposits on high-temperature surfaces has been the wastage of metal spacers, hangers and supports exposed to flue gas temperatures. Also in boilers designed to produce steam above 1000 F, the high-temperature superheater elements have suffered from corrosive attack, probably caused by vanadium pentoxide which at temperatures above its melting point, namely 1220 F, is liable to produce fluxing of the protective oxide layer on the metal surfaces. Laboratory work has shown that sodium sulfate and vanadium pentoxide were active constituents causing the attack of high-temperature steels and alloys (3, 4).

At temperatures between 1022 and 1112 F the attack disappears and in boilers designed to operate at steam temperatures below 1000 F it is probable that metal wastage is caused by acid sulfates rather than by the direct oxidizing action of vanadium pentoxide.

A more serious problem associated with the use of heavy fuel oil in boilers operating with a final gas temperature lower than 350 F is the corrosion of the low-temperature surfaces swept by the flue gases (5).

During combustion, sulfur in the oil is oxidized to SO_2, a small amount being converted to SO_3. Laboratory experiments have shown that the oxidation of SO_2 to SO_3 by atomic oxygen can take place in the flame during combustion (6, 7), or alternatively the conversion may occur during the passage of the flue gases over the hot superheater metal by the catalytic action of iron oxide (8). It is possible that SO_3 is produced in both ways.

SO_3 combines with water vapor in the flue gases to form sulfuric acid which condenses on the cooler metal surfaces, the possible strength varying between 50 and 70 per cent (9, 10). Laboratory experiments have shown (11) that variations in the sulfuric acid content of the flue gases did not affect the concentration of the condensate which was solely dependent on the water vapor content and the surface temperature.

The amount of SO_3 which may possibly occur in the flue gases can be shown from the probable flue gas composition given in Table III.

Assuming 1 to 3 per cent of the sulfur in the oil is converted to SO_3, the flue gases will contain amounts varying from 20 to 60 ppm by volume or 1 to 3 lb 1000 lb oil.

The effect of SO_3 on the metal surfaces is shown by the rapid corrosion and blockage of the cold section of air-heaters, and the corrosive attack of metal ducting and the runners and blading of ID fans. For example, in one boiler serious airheater blockage occurred after several hundred hours' operation, tube replacements being required after one year in service. The problem of low-temperature corrosion is related therefore to the SO_3 content of the flue gases and the metal temperature.

Selection of Additives

The use of additives in oil-fired boilers is concerned therefore with:

(i) The modification of the character of deposits formed on high-temperature surfaces by the constituents of oil ash.

(ii) The alleviation of corrosion and blockage difficulties resulting from the deposition of sulfuric acid on the low-temperature surfaces.

Experiences with the use of additives in modern oil-fired boilers are summarized as follows.

Loss of boiler availability arising from the formation of bonded deposits on high-temperature surfaces is associated with the deposition of low-fusion-point compounds formed from the oil ash.

Additives which have been used mainly to raise the fusion point of the deposited material include calcium oxide, magnesium oxide and magnesium carbonate. Chemically inert materials such as silica, kaolin and p.f. ash have also been applied to modify the physical properties of the deposited material and to destroy its bonding properties.

Laboratory experiments, supplemented by boiler trials, have been carried out (12) to investigate the effect of these additives on the characteristics of the deposits and it was found, at that time, that dolomite was the most effective and economical. As a result, dolomite has had a wide application and is being used in boiler plant in many parts of the world.

Dolomite is a mineral containing in its purest form 45 per cent $MgCO_3$ and 54 per cent $CaCO_3$. When injected into boiler flue gases it combines with SO_3 to form the corresponding sulfates which are solids having a high fusion point and a powdery, friable deposit is deposited on the high-temperature heating surfaces which can be removed with less difficulty than oil ash deposits alone.

Laboratory experiments showed that the fusion point of oil ash was significantly raised by mixing the additive in the proportion of 1 dolomite to 1 oil ash and it was claimed that when using similar amounts in actual boiler plant the formation of bonded deposits was prevented. Other investigators have found it necessary to increase the dosage to 3 to 1 oil ash or to adjust the injection rate on the basis of the amount of deposit forming radicals, present in the oil ash (13).

Experiments with gas turbines (14, 15) showed that

TABLE 1 SUMMARY OF EXPERIENCES WITH DOLOMITE

Country	Company or Authority	Power Station	Dosage Rate	Method of Injection into Furnace	Advantages	Disadvantages
United States of America	Florida Power Corp	Inglis	Ratio: Dolomite / Oil ash = 1 / 1	As a slurry in oil	Reduced slag formation and superheater blockage. Reduced corrosive quality of flue gases, lowered dewpoint from 270 to 150 F	Blockages in oil supply lines and strainers. Burner nozzle wear
United States of America	Public Service Electric and Gas Co	Kearny	Dolomite / Oil ash = 2 / 1	As a slurry in oil	Reduced bonded deposit formation on superheater surfaces	Pump wear. Blockage in convection superheater
United States of America	Public Service Electric and Gas Co	Sewaren	Dolomite / Oil ash = 1 / 1	As a slurry in oil	No definite conclusions	Slagging in combustion chamber and on superheater tubes
United States of America	Consolidated Edison Co of New York	Not stated	Dolomite / Oil ash = 1 / 1	As a slurry in oil	Rate of blockage in superheater probably reduced	Not very successful
Brazil	San Paulo Light and Power Co, Ltd	Piratininga	Dolomite / Oil Ash = 1* / 1	Injected into flame of each burner in in form of dry powder	Superheater deposits made friable	Slagging in combustion chamber
France	Electricité de France	Nantes Cheviré	2.0 lb/1000 lb oil	Injected as dry powder through two opposing coal burners	Superheater deposits made dry and powdery	Rapid fouling in superheater even with more frequent soot blowing
France	Electricité de France	Dieppedalle	2 to 3 lb/1000 lb oil	As a dry powder: (i) into flame (ii) top of combustion chamber	None	Slag formation on brickwork round burners. Rapid superheater fouling
Great Britain	Central Electricity Generating Board	Southport	6 lb/1000 lb oil	As a dry powder through common windbox to 4 burners	Reduced dewpoint of flue gases from 300 to 240 F	Caused blockage in superheater

* Later added at a rate based on amount of deposit forming constituents in oil ash

magnesium oxide was more effective then dolomite in preventing the formation of bonded deposits when used in the ratio of $MgO:V_2O_5 = 3:1$ and $MgO:Na_2O = 2:1$ and, as a result, greater use of this additive is being made in the United States of America. Also the theoretical amount of MgO required to neutralize the SO_3 content of the flue gases is less than half the dolomite requirement and, in consequence, the risk of blockage in the gas lanes is correspondingly reduced.

The residence time of the products of combustion through the boiler is about 3 or 4 seconds and, to provide intimate contact between the additive and SO_3 in the flue gases, the material should be in the form of a fine powder.

Little work has been done to determine the limits of particle size which are effective but American users recommend that 95 per cent of the powder should have a particle size not exceeding 50 microns.

At Dieppedalle Power Station (16) trials have been carried out with supplies of dolomite having a varying particle size range. In each trial the material deposited on the superheater tube surfaces was fully sulfated which led to the conclusion that within the size limits used, namely 50 to 80 per cent less than 40 microns, particle size was not a dominant factor affecting the neutralization of SO_3. Details are not available of the length of time the additive remained on the heating surfaces, nor of the degree of sulfation of the particles entrained in the flue gases leaving the air heater.

The longest time of contact between an additive and the products of combustion will be obtained when the point of injection is near the flame. The additive may be used in the form of a dry powder or as a suspension in water which is carried by air into the combustion chamber, or, alternatively, it may be added to the main oil supply in the form of an oil slurry.

When used dry the dosage rate may be controlled by using one of the various types of chemical feeders which are available commercially, the dry powder being fed into the throat of a nozzle using compressed air to convey it into the boiler. Care should be taken to keep the powder dry and, to preheat the compressed air supply.

Ideally, the additive should be fed into the flame of each burner but in large modern boilers this is not always convenient and a compromise has been adopted, the additive being injected at several points distributed around the combustion chamber.

The oil slurry method is most favored in the United States of America. It has the advantage of delivering the additive directly to the flame of each burner. Experiences have shown, however, that blockage of the pipelines and strainers is likely to occur, accompanied by pump wear and abrasion of the burner tips. Moreover, precise control over the dosage rate is not possible at all times when using spill-over burners. Similar experiences were reported in Italy (17) where a change to the dry method of feeding is giving satisfactory results.

Dolomite was first used by Babcock and Wilcox, Ltd., at the Inglis Power Station of the Florida Power Corporation using 1 part dolomite to 1 part oil ash, pilot-plant tests having shown that when used in this ratio the fusion point of the oil ash was raised from 2100 to 2730 F. Periods out of service caused by deposit formation were less frequent and cleaning was comparatively easier.

In France, at Nantes-Cheviré Power Station operated by Electricité de France, dolomite was applied to alleviate superheater fouling by hard, bonded deposits which could only be removed by hand chipping and scraping when the boiler was off-load. When 2 to 4 lb dolomite per 1000 lb oil were injected through opposing corner burners the material deposited on the heating surfaces was friable and lightly sintered. Sootblowing did not remove the deposits but cleaning off-load was considerably easier. It was found, however, that when using amounts in excess of 3 lb 1000 lb oil, serious blockage difficulties occurred in a few weeks by a deposit containing calcium and magnesium sulfates and oil ash. The dosage rate has been reduced with satisfactory results, to a rate of 1.8 lb 1000 lb oil.

Similar superheater troubles were experienced at Dieppedalle Power Station when dolomite was used to alleviate airheater corrosion.

At Piratininga Power Station, San Paulo Light and Power Co., superheater blockage occurred after 2000 hr operation, accompanied by the wastage of the tube supports (see Fig. 1). To alleviate this trouble dolomite was injected as a dry powder into the flame of each burner initially in the ratio of 1 lb dolomite to 1 lb oil ash, but later in relation to the amounts of scale forming radicles present in the oil ash. This was found to be equivalent to about 2 parts dolomite to 1 part oil ash. Troubles arising from superheater blockage were reduced but slagging occurred in the combustion chamber at burner level and on the wall facing the burners.

The use of dolomite did not materially reduce the wastage of the uncooled superheater supports, and other protective measures were applied.

The best known solution to this problem is the use of cooled supports.

A summary is given in Table IV of the amounts of dolomite which have been used at several power stations including a brief indication of the advantages and disadvantages which have been observed.

American experiences with the use of magnesium oxide in the form of an oil slurry are varied, considerable difficulties having been experienced for the reasons stated above to control the dosage rate.

The fouling of airheaters and the corrosion of the metal of airheaters, ducting and I.D. fans have been the cause of frequent outage (see Fig. 2). Moreover the concrete walls of electrostatic precipitators have suffered serious attack. In several instances the complete renewal of the cold-end section of the airheater has been required after a year in service and the projected use of oil firing in boilers served by airheaters not having a separate cold-end section, or airheaters with narrow gas passages, is the cause of some concern.

Investigations have been carried out to find suitable additives which will alleviate these troubles. Materials which have been used include dolomite, ammonia gas and sodium carbonate which react chemically with sulfuric acid forming the corresponding sulfates. Also trials have been made with liquid coal tar bases which act as an inhibitor and protect metal from acid attack.

A brief account will be given of the results of boiler trials with various additives, the design characteristics of the boilers concerned being summarized in Table V.

Boiler Trials with Dolomite

(i) *Dieppedalle Power Station, Electricité de France*

Operating difficulties at Dieppedalle were mainly concerned with the rapid corrosion and blockage of the cold end section of the tubular airheater. The oil used contained about 4 per cent of sulfur and when operating without an additive, tube blockage occurred in several weeks. The cold-end section, containing 288 tubes, was completely renewed after one year in service, the center section in 5 years. Corrosion also occurred in the I.D. fans and the blades and runners have been replaced several times since the station was opened in 1949.

In 1955 trials were carried out by the station staff to observe the effect of dolomite on airheater corrosion.

The additive was injected into the flue gases as a dry powder by means of preheated compressed air, using a vibratory chemical feeder to control the dosage. From 2 to 3 lb dolomite 1000 lb oil were used, the hourly rate being 30 to 50 lb h.

Observations were made when dolomite was injected separately at three points in the boiler system as shown in Fig. 3, namely:

(*a*) Into the flame of two burners in opposite walls of the combustion chamber.

(*b*) At the top of the combustion chamber immediately in front of the pendant superheater.

(*c*) Above the top section of the airheater.

Fig. 1.—Wastage of a superheater bracket

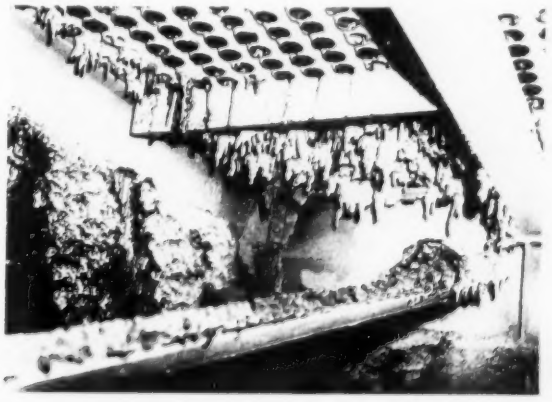

Fig. 2.—Deposits on the cold-end section of a tubular air heater

When injecting dolomite into the flame, slagging quickly developed on the refractory brickwork near the burners threatening its destruction and for this reason the trial was stopped. The number of tubes holed in the cold-end section of the airheater was less than in previous runs without dolomite and it was believed that there had been a slight reduction in the rate of metal corrosion.

When dolomite was injected at the top of the combustion chamber, deposits consisting mainly of calcium and magnesium sulfates rapidly formed on the convection superheater surfaces. Heat transfer was reduced and the draught differential across the boiler increased at a rate of 0.75 in. month. Although the deposits were dry and friable they could not be removed by sootblowing using air at a pressure of 570 psi. The deposits within reach from outside could be detached by hand lancing but the boiler had to be shut down for thorough cleaning. In this trial, which lasted for 11,000 hr, 24 tubes were holed in the lowest section.

When dolomite was injected above the airheater, acidic deposits containing magnesium sulfate, calcium sulfate and free SO_3 caused blockage in the cold-end section. The deposits were completely removed by water washing. In this trial of 11,000 hours' duration, 51 tubes were holed.

In these trials the SO_3 content in the flue gases was not determined. Theoretically 2 lb dolomite 1,000 lb oil is equivalent to 1.74 lb of SO_3 or about 36 ppm SO_3 by volume in the flue gases. Blockage was measured by the increase in draught differential across the boiler passes, and the rate of corrosion by the direct observation of the number of tubes holed.

When using amounts greater than 3 lb 1000 lb oil, blockage occurred in the superheater and airheater corrosion was not significantly reduced.

(ii) *Nantes-Cheviré Power Station, Electricité de France*

During the early days of operation without additives, using oil having a sulfur content about 4.0 per cent, a sticky deposit containing mainly iron sulfate and free SO_3 formed on the cooler airheater surfaces swept by the flue gases. Serious corrosion and blockage occurred in the cold-end section which had to be retubed after 2 years.

To reduce these troubles, 2 to 4 lb dolomite 1000 lb oil were injected into the combustion chamber through the ports of two coal burners not in use in opposite corners of the furnace. The rate of injection was controlled by a vibratory feeder using hot compressed air to deliver the charge to the boiler. Deposits containing oil ash calcium and magnesium sulfates caused tube blockage in one month and the airheater had to be cleaned by washing off-load, every three or four weeks. The cold-end section had to be retubed after a year but rate of metal wastage was slightly less than previously.

Subsequently, dolomite was injected simultaneously into the flue gases at the inlet to the airheater and the combustion chamber using at each point 1.8 lb dolomite 1000 lb oil (see Fig. 4). The SO_3 content of the flue gases at the economizer inlet was found by direct determination to be 27 ppm by volume, i.e., about 1.3 lb SO_3 1000 lb oil remained in the flue gases after the injection of dolomite into the combustion chamber. Tests showed that the dewpoint of the flue gases at the airheater outlet was not significantly lowered and it was concluded that the additive would not have a marked effect on airheater corrosion when injected immediately before the airheater.

Dolomite was injected into the combustion chamber of two other boilers of similar design, from the first days of commissioning using 2 lb 1000 lb oil. These boilers operated for more than one year without having serious airheater corrosion, but after 3 years several tubes were holed.

(iii) *Southport*

Trials were carried out at Southport to observe the effect of dolomite on the SO_3 content of the flue gases when using medium fuel oil having a sulfur content of 3.8 per cent. Dolomite, having an average particle size of 3 microns, was injected as a dry powder by compressed air into the common wind box at four separate points near the burners using a plate-type feeder (see Fig. 5).

The SO_3 content of the untreated flue gases was 20 ppm by volume, indicating that about 1 per cent of the sulfur content in the oil had been converted to SO_3. When injecting 8 lb dolomite 1000 lb oil, the SO_3 content was reduced to 11 ppm. Tests with a corrosion probe (18) showed that the rate of acid attack had been reduced from 106 to 17 mg iron 100 sq cm hr. When the rate of injection was increased progressively from 2 to 13 lb 1000 lb oil, the rate of acid build-up (R.B.U.) as determined by the dewpoint meter was reduced from 180 to 2 micro amps min and simultane-

TABLE 5 CHARACTERISTICS OF BOILERS

Station	Maker	Final steam Pressure, psi	Final steam Temp., °F	Capacity, lb/h	Final Gas Temperature °F	Airheater Type
Southport	Yarrow and Co., Ltd.	275	720	85,000	350	Tubular. One section mild steel
Marchwood	John Thompson Water Tube Boilers, Ltd.	925	915	550,000	350	Tubular. Two sections mild steel and cast iron
Nantes-Cheviré (Electricité de France)	Combustion Engineering, Stein and Roubaix	1500	986	500,000	290	Tubular. Two sections mild steel
Dieppedalle (Electricité de France)	Sulzer Brothers, Ltd.	1275	960	200,000	300	Deka. Tubular. Three sections of cast iron
Bankside	Foster Wheeler, Ltd.	950	925	375,000	330-340	Tubular. Two sections, mild steel and cast iron
Piratininga (San Paulo Light and Power Co., Ltd.)	Babcock and Wilcox, Ltd., and Goldie-McCulloch	875	925	850,000	350	Tubular. Three sections, mild steel
Civitavecchia (Societa Termoelettrica Tirrena)	Combustion Engineer and Superheater, Inc.	875	905	650,000		Ljungstrom plate
Deptford	Foster Wheeler, Ltd.	950	925	250,000	270	Tubular. Two sections, mild steel
Poole	International Combustion, Ltd.	950	940	340,000	350-360	Useo. Plate. Mild steel

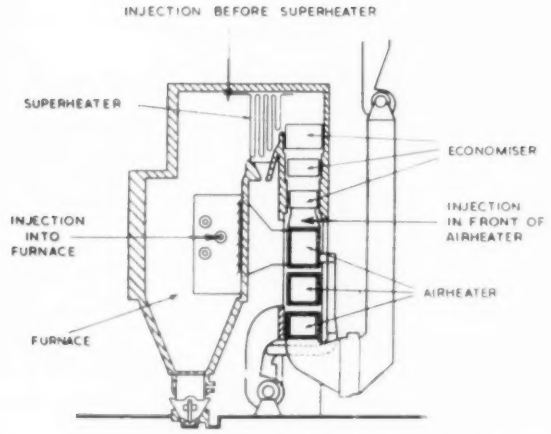

Fig. 3—Diagram showing points of additive infection in the Sulzer boiler at Dieppedalle, Electricité de France, above

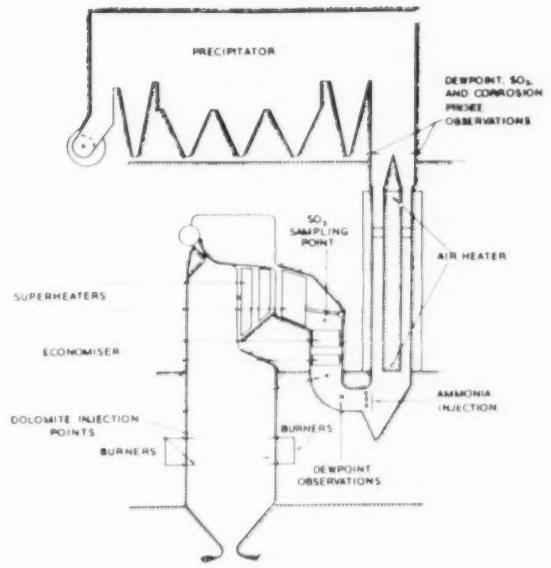

Fig. 4—Diagram showing points of injection at Nantes-Chevire Power Station

ously the dewpoint was reduced from 290 to 240 F. The excess of dolomite over theoretical requirement varied from 200 to 1200 per cent. Samples of dust taken at the airheater outlet when using 10 lb dolomite/1000 lb oil contained 60 per cent dolomite, one-seventh of which had been converted to sulfates. It was found that a large excess of dolomite was required to suppress the acid dewpoint, 14 lb/1000 lb oil being required. Serious superheater blockage occurred within 35 hr causing boiler shut-down and damage to the brickwork in the furnace. When the injection of dolomite was deliberately stopped, an acid dewpoint was almost immediately observed suggesting that the reaction between dolomite and SO_3 occurred while the powder was suspended in the flue gases. It is probable that the additive would have been used more effectively if longer time of contact had been possible. It was concluded that the amount of dolomite required to suppress completely the acid dewpoint would produce, when injected into the furnace, serious slagging and superheater blockage.

(iv) *Marchwood*

Dolomite was injected as a dry powder into the furnace through several ports at the top of the combustion chamber and, later, into the flame of two pairs of burners located in opposite walls of the combustion chamber (see Fig. 6). When using in each case 1.3 lb/1000 lb oil, slagging developed on the superheater tubes and in the latter case on the walls of the combustion chamber also. Corrosion and blockage in the air heater were not significantly reduced but further tests are being arranged in which improved methods of feeding will be employed.

Ammonia gas was first used as an additive at Brimsdown in 1944 (19) to neutralize the acid flue gases of a stoker-fired Loeffler boiler which was experiencing serious corrosion in the Ljungstom airheater. Deposits of ammonium salts caused rapid blockage of the airheater and the use of ammonia was abandoned.

Recently, British Petroleum Company, Ltd. (20), have carried out trials on an oil-fired pilot plant to observe the effect of ammonia gas on the dewpoint of the flue gases. The trials showed that the acid dewpoint was completely suppressed, and it was concluded that when adding a slight excess over theoretical requirement, the reaction product would be mainly the normal salt, ammonium sulfate. It was suggested that ammonia would be used most effectively when injected within the temperature range of 300 to 1100 F, preferably at 600 F. As a result of this work, ammonia distribution systems have been developed suitable for use in large modern boilers.

Experiences with the use of ammonia gas additive in modern boilers will be considered briefly hereafter.

(v) *Dieppedalle Power Station*

Ammonia gas supplied in cylinders was injected as a mixture in compressed air through a grid distributor installed in the ducting at the economizer inlet where the flue gas temperature was 850 F.

The dewpoint of the untreated flue gases was about 290 F which according to the curve given by Rylands and Jenkinson (21) corresponds to an SO_3 content of about 40 ppm by volume requiring 0.8 lb ammonia/1000 lb oil for neutralization.

When using 0.66 lb/1000 lb oil the acid dewpoint of the flue gases remained unchanged, and to suppress it 1.3 lb/1000 lb oil were required, i.e., 60 per cent excess over theoretical requirement. Serious airheater blockage occurred within 12 days, necessitating the shutting down of the boiler to clean the airheater surfaces by water washing. The deposits consisted mainly of acid ammonium sulfate, iron sulfate and a little free SO_3. When the airheater surfaces were examined after 5000 hr in service the attack of the metal appeared to be less than in previous runs. It was decided that in order to assess the economic value of ammonia it would be necessary to examine the surfaces again after a further six months' operation, taking into account the number of times it had been necessary to take the boiler out of service to wash the airheater surfaces. Airheater washing is carried out while the surfaces are hot in order to ensure that they remain dry when the process is completed.

In an attempt to reduce the frequency of boiler outage for airheater cleaning, a shot cleaning process was installed. The steel shot, about $\frac{1}{4}$ in. in diameter, rapidly became coated with a deposit of acid ammonium sulfate which increased the rate of blockage by retaining the shot in the gills of the airheater. A boiler is now being operated using shot cleaning alone, but analysis of the solid material removed by the treatment indicates that corrosion of the metal is proceeding. Ammonia additive is still in use on three other boilers.

(vi) *Nantes-Chevire Power Station*

The Electricité de France decided to use ammonia in place of dolomite which had not been found effective in reducing airheater corrosion. The injection began in November 1956. The additive was introduced into the flue gases through a distributing grid designed by the power station staff which was installed in the ducting immediately ahead of the airheater. The temperature of the flue gases at the point of injection was 635 F and the acid dewpoint 290 F. The SO_3 content, found by direct determination, was 28 ppm by volume which is equivalent to 1.4 lb SO_3 1000 lb oil. Initially the theoretical amount of ammonia required to neutralize the SO_3 content was used, namely 0.6 lb 1000 lb oil, and in an hour the dewpoint of the gases at the airheater outlet was reduced to 140 F indicating that the acid dewpoint had been suppressed. Continuous usage of this amount of ammonia led to rapid airheater blockage and, to maintain boiler availability, the airheater surfaces had to be cleaned off-load by washing with water once a week.

In a second trial the distributor was transferred to a point ahead of the economizer inlet where the flue gas temperature was 850 F and the ammonia was injected as a mixture in air at a pressure of 5 to 8. As a result boiler outage for cleaning was required at first only once in four weeks, but was later increased to once in two weeks. Samples of deposits from the airheater surfaces contained acid ammonium sulfate and free SO_3, and after several months' operation a number of tubes in the cold-end section of the air heater showed signs of thinning. Corrosion was also severe where the metal temperature was about 400 F.

In an attempt to reduce the rate of airheater corrosion the rate of injection was raised to 1.3 lb 1000 lb oil, an excess of 100 per cent over theoretical requirement. When the trial had been in progress 48 hr the draught differential increased from 2.6 to 3.1 in w.g. In a second trial, on a boiler of similar design when using 0.4 lb 1000 lb oil, the draught differential remained unchanged after 48 hr and it was inferred that with higher rates of ammonia usage, increased fouling was probable. Consequently ammonia is now injected on both boilers at the lower rate but with no effect.

(vii) *Marchwood Power Station*

When operating the oil-fired boilers at this station without an additive the low-temperature section of the airheater became blocked within 5 to 6 weeks with a deposit containing mainly iron sulfate, and during the same period the multi-cyclone grit arrestors became choked with a hygroscopic deposit. Corrosion on the metal was serious and, after 3500 hr steaming, the cast-iron tubes in the low-temperature section of the air-heater had to be replaced.

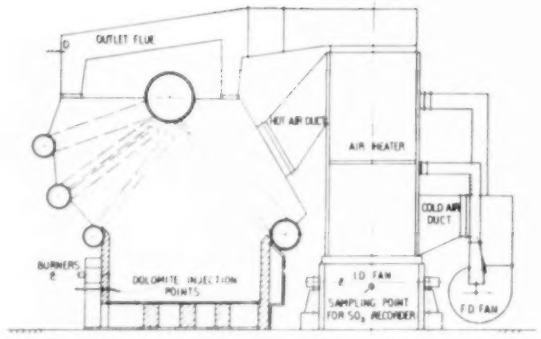

Fig. 5—Diagram showing points of injection at Southport Power Station

The dewpoint temperature of the untreated flue gases varied from 260 to 290 F, the SO_3 content of the flue gases being 44 ppm by volume which is equivalent to 2 lb SO_3 1000 lb oil.

Ammonia gas was used in an attempt to alleviate air-heater corrosion and blockage, the additive being injected with air through a distributor grid, designed by the Southern Division at a pressure of 7.5 lb sq in. Initially the distributor was installed at the economizer outlet where the flue gas temperature was 650 F. When using the theoretical amount of ammonia to neutralize the SO_3 content, namely 0.86 lb 1000 lb oil, in two weeks the second pass of the high-temperature section became blocked with a deposit containing 700 per cent of acid ammonium sulfate.

To prevent the occurrence of blockage in the hot section of the airheater and to localize deposit formation in the cold-end section which could be washed more conveniently the distributor grid was moved to the inlet of the cold section. At this point the temperature of the flue gases was 450 F. Using 0.86 lb ammonia 1000 lb oil the cold-end section became completely blocked as before, within a period of two weeks, with deposits containing acid ammonium sulfate.

When the dosage was increased to 1.72 lb 1000 lb oil, blockage in the airheater was more severe and, in addition, the grits collecting in the receiving hopper being hygroscopic could only be removed by rodding.

The point of injection was moved later to the economizer inlet, the temperature at the point of injection being 920 F, with similar blockage troubles, the draught differential across the airheater having doubled in two weeks. In all the trials the acid dewpoint was completely suppressed.

The heating surfaces could not be cleaned on-load and the most effective method was by water washing when the boiler was shut down.

(viii) *Trials on a Coal-Fired Boiler*

Trials with ammonia additive have been carried out by Imperial Chemical Industries, Ltd., on a stoker-fired boiler at Heysham to reduce corrosion in a plate-type air-heater. The average sulfur content of the coal used was 2.0 per cent and the dust burden of the flue gases entering the airheater 0.25 grain cu ft at NTP. Ammonia was injected a short distance away from the inlet to the air-heater using 100 ppm by volume and the temperature at the point of injection was 490 F. The acid dewpoint

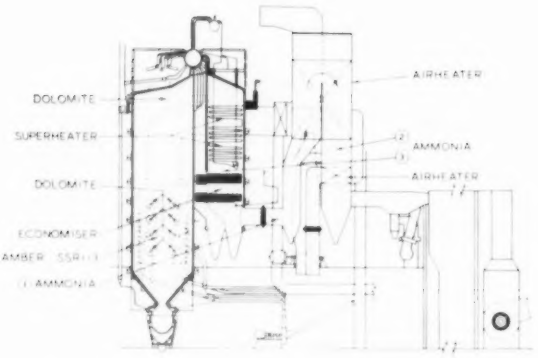

Fig. 6—Diagram showing points of injection at Marchwood

was suppressed and, after several hundred hours' operation, the deposits on the metal surfaces were dry and friable and could easily be removed by rodding and there have been no blockage difficulties. Details of the effect of the additive on the rate of corrosion are not available.

A series of heterocyclic tertiary amines obtained from coal tar and sold under the trade name "Teramin" have been used to inhibit the corrosion of iron and steel by sulfuric acid in the acid pickling process. The suppliers, Midland Tar Distillers, Ltd., in collaboration with Shell Petroleum Co., Ltd., have developed the use of Teramin to prevent the corrosion of low-temperature surfaces in oil-fired boilers. When the liquid is injected into hot flue gases it evaporates and eventually condenses on the cooler metal surfaces as a liquid film which is impervious to attack by sulfuric acid solutions. Moreover, Teramins may be selected which have a boiling point within the range of the acid dewpoint of the flue gases. Laboratory studies suggested that the corrosion of steel surfaces and rates of sulfuric acid deposition were reduced at all temperatures below the acid dewpoint of the hot flue gases by the use of coal tar bases (22).

Trials with Teramin have been carried out by the Central Electricity Generating Board, in collaboration with the suppliers, at Bankside and Marchwood.

At Bankside the additive was fed by drip feeders into compressed air nozzles which injected the liquid-air mixture into the flue gases entering the low-temperature section of the airheater. The oil used had a sulfur content greater than 3.0 per cent, the dewpoint of the flue gases being 300 F.

With a rate of addition equivalent to 0.45 lb 1000 lb oil, corrosion of the cast-iron tubes in the cold section of the airheater was reduced by two-thirds that observed with untreated gases. Corrosion of the ducting leading from the airheater to the gas-washing plant was also alleviated, but a black carbonaceous deposit, possibly oil ash and unburnt carbon particles, containing traces of liquid additive formed on the surfaces of the tubes and the tube sheet. In tests made later, using 0.35 lb 1000 lb oil it was found that 80 per cent inhibition was obtained from time to time and coagulation of the dust in the flue gases was reduced. Teramin is now in continuous use on one boiler.

At Marchwood, Teramin was injected into the space between the hot and cold sections of one-half of the airheater, the untreated half being used as a control.

During the trial, which lasted for 700 hr, the average sulfur content of the oil was 4.0 per cent and the final flue gas temperature 350 F. The dewpoint of the flue gases was similar on both sides of the airheater, having a range of 250 to 290 F. When the surfaces were examined at the end of the trial, a black deposit, containing oil ash, cokey matter and traces of liquid additive, was found on the treated side. There was less deposited material on the untreated side.

When the airheater was cleaned by washing, analyses of the wash water showed that there was 30 per cent less soluble iron in the effluent from the treated section and it appeared that the additive had inhibited attack of the metal during the washing process.

Unfortunately, during the trial the injection system did not provide for a uniform distribution of the liquid additive in the flue gases at all times of operation and only a small quantity condensed on the metal surfaces, most of it passing as vapor in the flue gases to the chimney. Probably the use of a homelog having a higher boiling point range would have been more effective and further trials are being arranged to investigate it.

Trials have been carried out at Marchwood with an additive S.S.R.113 marketed by Amber Chemical Co. The additive was applied as a dry powder crushed to pass a B.S.S. 200 mesh sieve. One and three-tenths lb 1000 lb oil were injected by air into the flame of two pairs of burners in opposite walls of the combustion chamber using a patented feeder to control the dosage rate (see Fig. 6). The boiler operated satisfactorily for 1400 hr without airheater blockage, and the gritty material collected in the grit hoppers was free flowing and caused no handling difficulties. The multicell grit collectors also operated throughout the trial without difficulties. In the early stages a layer of a dry powder deposit was observed on the top few rows of tubes in the secondary superheater. With continued boiler operation the thickness of the layer of deposit did not increase and blockage of the spaces and gas lanes did not occur. The dewpoint of the untreated gases was about 290 F. Dewpoint observations made during the trial showed a wide variation, the minimum value recorded being 240 F and the average about 260 F, showing that the acid dewpoint temperature had been reduced. The deposits on the airheater surfaces consisted almost entirely of iron sulfate.

When cleaning the airheater by water washing, samples of the wash water effluent were found to contain soluble iron equivalent to 1200 to 1300 lb per 1000 hr operation, whereas the iron content in the washings following a steaming period without additive contained 2600 lb of soluble iron per 1000 hr operation. If this method of observing corrosion conditions is reliable then in this case the rate of corrosion had been reduced by approximately 50 per cent.

The thin hard deposit which formed on the tube surfaces was not removed as readily as when using other additives, a higher water pressure being required. The use of S.S.R.113 has been extended to other boilers in the power station, but the same degree of freedom from blockage difficulties has not occurred.

Trials are also being carried out in boilers at other power stations operated by the Central Electricity Generating Board but the observations available are too few for a significant conclusion to be drawn.

Arising from the work at Bankside with coal tar bases, consideration was given to the possible use of alkaline solutions to neutralize the SO_3 content of the flue gases. Experiments have been carried out to observe the effect of soda ash solution on the rate of corrosion when injected into the space between the hot and cold sections of the airheater. A 15 per cent aqueous solution was injected by air in the form of spray at a rate equivalent to 0.08 lb 1000 lb oil. Difficulty was experienced in obtaining a uniform distribution of the additive in the flue gases but it is claimed that metal corrosion was reduced from 0.004 in. of tube thickness per 1000 hr to less than 0.002 in. The process has been patented (23).

An investigation (24) of the factors controlling the oxidization of sulfur dioxide to sulphur trioxide in a small kerosine-fired combustor showed that excess air greatly influenced sulfur trioxide formation. In actual boiler plant at Bankside (25) the dewpoint of the flue gases was lowered from 340 to 300 F by increasing the CO_2 content from 10 to 13.5 per cent. The rate of metal wastage reduced from 0.125 to 0.01 cm per M hrs.

At Marchwood and Poole, airheater corrosion and blockage has been reduced, as indicated by an increased number of steaming hours between cleaning periods, by operating with a CO_2 content of about 14.7 per cent. Moreover, by raising the CO_2 content of the flue gases from 12 to 15 per cent the SO_3 concentration was reduced from 40 to 8 ppm.

Discussion

Where loss of boiler availability is caused mainly by the formation of bonded deposits on high-temperature surfaces, the only method of alleviation known at present is the use of refractory materials such as dolomite, magnesium oxide and magnesium carbonate.

Trials have shown that when dolomite was injected into the combustion chamber, deposits containing calcium sulfate, magnesium sulfate and oil ash formed on the superheater tubes, causing blockage. The deposited material could not be removed by soot-blowers using compressed air while the boiler was steaming, but cleaning off-load was considerably easier.

Dolomite and magnesium oxide did not appear to have a marked effect on low-temperature corrosion.

It is doubtful if solid additives of the type now in use will be significantly effective in reducing airheater corrosion. The rate of reaction between a solid particle suspended in the flue gases and SO_3 is slow, and time of contact in a boiler system is limited. Initially, the outer surface of an individual additive particle will become coated with a skin of the corresponding sulfates of the metals leaving an inner core of unchanged material. Penetration of the outer skin will proceed at a much slower rate and the particles will become less reactive with SO_3 as they pass through the boiler toward the airheater where, in all probability, no further interaction occurs. It is possible that the solid additive particles deposited on the airheater surfaces are nuclei on which the acid vapor condense.

It should be noted that in pulverized-fuel-fired boilers the aqueous solution of deposits on the airheater surfaces is usually alkaline, the alkalinity being derived from solid particles having an inner core of calcium oxide which passed through the boiler system unchanged.

Ammonia gas can only be effectively used at temperatures below its ignition point and therefore its use is restricted to the control of low-temperature corrosion. The reaction between gaseous NH_3 and SO_3 is more rapid than that between solids and SO_3 as is shown by the complete suppression of the acid dewpoint. Probably all the SO_3 in the flue gases is removed as solid ammonium sulfates which are deposited on the heating surfaces causing blockage in a few weeks. Variations of the dosage rate and the temperature of the point of injection appeared to have no significant effect on boiler availability, moreover the rate of blockage increased when the rate of injection was raised. The deposits consisted mainly of acid ammonium sulfate and it is probable that ammonia gas also combined with SO_2 and O_2 in the presence of oil ash. Experiments at the Central Electricity Research Laboratory showed that when pure ammonium sulfate was heated in a thermal balance it remained unchanged at temperatures below 390 F. Between 400 and 490 F ammonium acid sulfate was formed which was stable; above 490 F the salt volatilized. Ammonium acid sulfate melts at 296 F, which, on surfaces at temperatures exceeding 400 F, will produce an acid flux and attack the metal.

The disadvantages experienced with the use of ammonia should not be allowed to overshadow the possible advantage of its rapid reaction with SO_3. Attention should be directed toward methods of modifying the acidic nature and physical characteristics of the reaction products by introducing into the flue gases simultaneously, amounts of an inert material such as kaolin, pulverized-fuel ash and other similar materials. Experiences with ammonia in coal-fired boilers support this suggestions. For example, a trial at Heysham has been in progress for several months without blockage difficulties, the heating surfaces of a plate-type airheater being freed from deposits by on-load methods of cleaning, in this case the dust burden of the flue gases was 0.25 grains cu ft at N.T.P. Similar results have been reported at Deptford where in a stoker-fired boiler served by a tubular airheater, corrosion troubles have been significantly reduced by the use of ammonia even when operating with a final gas temperature under 300 F.

The dust burden in the flue gases of an oil-fired boiler is about 0.05 grains cu ft at N.T.P., and the SO_2 content of the order of 1500 ppm by volume. In pulverized-fuel-fired boilers the flue gases entering the airheater may contain 5.0 grains of dust cu ft and outages arising from airheater blockage and corrosion seldom occur, the sulfur dioxide content of the flue gases being similar to that in oil-fired boilers.

At Poole a modern boiler is being operated with coal and oil firing simultaneously in the proportion of 1:1. So far, airheater troubles have not been experienced. Also at the Vasteras plant of the Swedish Royal Board of Waterfalls simultaneous coal and oil firing in the ratio of 1 to 4 provided relief from airheater blockage and corrosion and the use of a mixture of pulverized-fuel ash and dolomite in an oil-fired boiler at Kearny, U.S.A., resulted in several thousand hours' trouble-free opera-

tion. On the other hand, at Nantes-Cheviré, when using dolomite and ammonia, airheater corrosion was not alleviated, but the amount of dolomite injected into the furnace was limited by the risk of superheater fouling.

A disadvantage associated with the use of additives, especially ammonia, is the need for water washing to clean the heating surfaces. The aqueous solutions of ammonium sulfates are acidic and metal corrosion will probably occur during the washing process. Moreover it is difficult to ensure that the metal surfaces are completely freed from acid reacting materials. Some relief has been obtained by the use of coal tar bases at Marchwood which inhibited the corrosive attack of the acid effluent. Ideally an additive should not incur the need for frequent water washing and should form reaction products which could be removed from the heating surfaces by sootblowing. Early experiences at Marchwood suggest that this condition has been partly achieved by the Amber Combustion additive.

The Central Electricity Generating Board are arranging boiler trials to investigate other possible additives including magnesium carbonate and metallic zinc. Zinc has been selected for its ability to produce zinc oxide smoke on which SO_3 might be adsorbed (26). Plant trials have already confirmed this possibility (27). The effect of various metal oxide smokes on the SO_3 content of the flue gases from fuel oils has been investigated by trials in small oil-fired furnaces (28).

The use of gaseous additives, such as CO, CH_4 and H_2 have been suggested (29) which, when injected below their ignition point, would reduce SO_3 to SO_2. SO_2 is less harmful and would pass out of the boiler in the flue gases without causing blockage in the airheater. The effect of these gases on the formation of SO_3 in flames has been studied (30) in a series of laboratory experiments.

Boiler operating conditions also play an important part in the conversion of SO_2 to SO_3 and combustion conditions should be controlled as near the point of smoke formation as practicable, but by so doing unburnt carbon losses are likely to be increased.

The possibility of finding a suitable additive for oil-fired boilers on the lines suggested is being actively investigated.

No attempt has been made to discuss the relative economic value of the various additives. In such a consideration it would be necessary to take into account the cost of cleaning the surfaces, the loss of output arising from boiler outage and the cost of the injection equipment and its maintenance.

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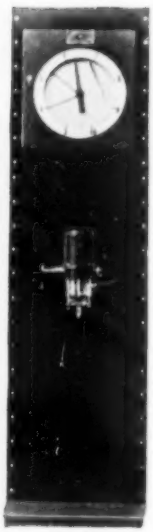
Appendix

Testing Techniques

The SO_3 content of the flue gases in oil-fired boilers is associated with the troubles which occur on both high- and low-temperature surfaces, and it is desirable to have a knowledge of the changes which occur in the SO_3 SO_2 ratio across the boiler passes. A knowledge of the SO_3 content of the untreated gases gives a measure of the amount of the original sulfur which has been fully oxidized and serves as a basis on which to calculate the amount of additive required.

A method of determining SO_2 and SO_3 in flue gases was developed by Corbett (31), and subsequently modified by Fletcher (32). Recently, further improvements of the technique have been made at the Central Electricity Research Laboratories by Jackson (33) who has produced a conveniently portable apparatus which gives reliable results.

Alternatively, the SO_3 content may be found indirectly from dewpointmeter observations by reference to curves published by Rylands and Jenkinson relating dewpoint temperatures to sulfuric acid concentration. Observations should also include determinations of the rate of metal corrosion. Several methods have been employed by various workers, including corrosion probe determinations (34, 35), direct measurement of metal wastage in the airheater itself (36) and analyses of samples of the effluent wash water for the soluble iron content. None of these methods is entirely satisfactory and work is now in progress to find a more reliable test.



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High Temperature Reactor Needed

S. T. Robinson and *R. F. Benenati*, Sanderson & Porter, in their paper, "A Pebble Bed Reactor Steam Power Plant", presented at the American Power Conference (See pages 49-52) pointed out that if one insists that nuclear power stand on its own feet economically, it is obvious that a nuclear power plant must have a fuel cycle cost lower than, and a net station heat rate at least equal to, that of a modern fossil fuel fired plant before it can be seriously considered as a part of a utility complex. High capital costs will initially limit its competitive position, but it is inevitable that these costs will be reduced by development and repetitive construction.

Present practices of the utility industry indicate that the only way to achieve a low heat rate is through the use of a high-temperature, high-pressure steam cycle. Obviously, such a steam cycle can only be attained with a reactor capable of operation at temperatures considerably above that of today's practices in reactor design. High-temperature operation requires that the reactor core materials be refractory in nature and that the reactor coolant, or heat transport fluid, be a non-corrosive gas of good nuclear, thermal characteristics.

Having these basic requirements in mind, a number of reactor types were examined and discarded because of what appeared to be complex fuel handling equipment, expensive fuel elements, undesirable thermal characteristics and the like. From this study emerged the Pebble Bed Reactor; a gas-cooled, graphite-moderated system in which a fuel in ceramic form was embodied in a spherical matrix. This is a thermal reactor, applicable as a U235 converter or a thorium-U233 breeder.

American Power Conference in Review—I

The twenty first annual meeting of the American Power Conference was again held at the Sherman Hotel in Chicago, March 31–April 2, inclusive. Registration was excellent again with about 3000 in attendance.

Peaking Service

The currently interesting subject of peaking service for public utility steam systems was covered in a two paper session.

"Automatic Plants for Peaking" by **B. B. Brownell** and **B. H. Hefner** pointed out that during the past four years, interest in specialized equipment for peaking has been increasing rapidly. Since this is a new concept, controversy over its soundness has arisen and settled down; the economics has been challenged and proved again and again; and equipment has been designed, produced and tested. Various methods of providing low cost peaking power are now being investigated by many companies. These methods include knocked down steam plants, gas turbines and pumped hydro in addition to diesel power in which the authors were interested and discussed.

As the authors stated, it is in the area of peak load generation that utility management is offered greatest opportunities for significant reductions in capital requirements in the 20-year expansion period ahead. A look at the daily load curves on a typical utility system serves to emphasize this point. By integrating all of the individual daily load curves together a typical annual load duration curve can be had. Even as a utility grows, said the authors, the shape of its load duration curve does not vary too much. It is common for a utility to have 20 per cent of its generating capacity supplying peak demands which amount to less than 10 per cent of the kilowatt hours. And it is this fact that accounts for the increasing interest in specialized packing power.

Modern steam plants have a heat rate expressed in Btu kilowatt hour lower than that of the most efficient diesel engine. They burn cheaper fuel so they get their Btu's for less money. However production costs for a steam plant increase very rapidly as the plant factor is reduced below 40 per cent. Therefore, while the steam plant is cheaper than the diesel in base load, it is very expensive to operate just on the peaks where the diesel becomes the cheaper.

A. O. White, R. J. Carpenter and **W. D. Marsh,** General Electric Co., teamed to present "Design Concepts of a Low Cost Gas Turbine Generating Plant for Peak Load Service." The paper described the results of a design study to develop a gas turbine and associated plant for electric utility peak load service. Both turbine and plant design detail and specifications were worked out to the point that prospective users may obtain price quotations for all material and labor necessary to construct the complete plant on any suitable site. Such quotations, it was reported, have been secured in two specific utility locations, with the result that plant cost is rather accurately and reliably known (See pp. 56–60).

Industrial Plants

A special symposium by industrial power users, equipment manufacturers and a consulting engineer discussing recent developments, installations and the importance of proper planning and flexibility in the design of industrial power generation plants was held.

R. W. Precious, Union Carbide Olefins Co., led off with his viewpoints. To Mr. Precious' way of thinking successful forward planning in an industrial power plant depends upon close coordination between the process engineers, utilities design engineers and equipment suppliers. The process engineer must keep the utilities engineer informed of his process requirements from the inception of the design through the completion of the project. The more the utilities designer knows of the basic project requirements and the possible variables, the better he will be able to decide on the optimum arrangement and selection of equipment to produce the power balance. It becomes obvious then, that a good steam and power balance is the necessary foundation on which to base a sound design of the utility services.

The actual power plant design must incorporate equipment selected to meet the basic requirements established by the type, size and importance of the process it serves. Four factors enter into this selection and each piece of equipment must be carefully analyzed to determine (1) reliability, (2) investment, (3) flexibility and (4) operating cost.

It is a recognized fact that once steam generation at say 200 psi has been justified, it does not cost a proportionately greater amount to raise the pressure level to 600

psi or higher. In plants requiring process steam at various pressure and temperature levels it is usually economical to generate all steam at a pressure equal to or greater than the highest process pressure required. Normal process requirements include pumps and compressors and these must be supplied with some form of driving energy. Herein is the main use for the steam and power balance sheet. The ideal plant would generate high pressure steam which in turn would be reduced in pressure by back pressure turbine drives to supply the energy for pumps and compressors or to generate electrical power for process. The low pressure exhaust steam would then pass through a series of heat exchangers completely satisfying the process heat requirements and then return to the boilers as uncontaminated hot condensate. This ideal balance occurs infrequently in plants. Instead, the process steam load is usually less than the corresponding horsepower equivalent of economical back pressure turbine drives. It is usually necessary to install pressure reducing stations for load flexibility and the problem of whether to purchase a portion of the electrical power or justify internal generation on a straight condensing principle comes into the considerations. This is a problem on which many papers have been written and the answer depends on many factors too extensive to go into at any one time.

Even partial power generation on a back pressure cycle must be evaluated accurately. Steam and power distribution systems must be constantly reviewed to permit a thorough analysis of the effect of new process loads. No new situation should be solved simply by doing what was done before or by what seems on the surface to be the best. The process requirements, distribution system and economics must be analyzed and a steam and power balance prepared.

H. R. Emery, St. Regis Paper Co., added still another industry view. The paper industry, which the author represented held, he felt, an advantageous position in the field of steam and electric power generation. A review of several paper mills shows that the pounds of steam per kilowatt hour required varies from 7 to 25. This steam is used in various processes, usually at pressure levels of 50 psig and 150 psig. The main users are the drying of paper as it passes over the dryer rolls on the paper machines and the cooling of wood chips into pulp in either batch or continuous process digesters. A good heat rate is obtained in some mills, where all boilers can be set up at the same pressure, in the 600-900 psig ranges. Higher pressures and temperatures are becoming common where topping installations are required. Due largely to this favorable heat balance, in 1957 the paper industry generated 17.1 billion kwhr of the 27.5 billion kwhr required, or 62 per cent of its use. It is predicted by one major supplier that by 1967, the paper industry will generate 75 per cent of the electric power used. It follows that there will be more and larger steam and electric power plants within the paper industry.

Another factor favoring generation is the availability of large quantities of by-products steam in a mill manufacturing kraft pulp. The per cent of total steam required furnished by each of these suppliers often falls in the following ranges:

Liquor burning—recovery furnaces	40–45 per cent
Bark burning	15–20 per cent
Fuel burning	35–45 per cent

The steam provided by these sources adds a complication to the accounting procedure in charging steam to electrical generation. There is little agreement in the industry as to the proper way to do this and the wide range of methods used results in a great lack of uniformity in the reported costs per kwhr generated.

Today, types and sizes of power plants vary widely within the paper industry. Most boilers are in the 100,000- to 250,000-lb-per-hr size range. The largest units are in the 500,000-lb-per-hr class, while the smaller ones may generate less than 10,000 lb per hr. Turbine generators are sized from 1000 kw to 40,000 kw, with most being in the 5 to 14,000-kw range. These units are almost all extraction type machines, either condensing or non-condensing. It is usual to point with pride at the modern, large, high-pressure power plants and try to indicate that these are typical of the paper industry. The truth is that these are in the front ranks of a broad band of development that is represented by the hundreds of power plants in existence in the industry. The most perplexing problem facing most power suppliers is the best use of the existing facilities when expansions are contemplated, and, as pointed out, much of the paper industry is faced with expansion.

The solution to the expansion problem in an old mill, depending on a series of economic factors, such as fuel costs, existing pressure level, purchase power dependability and many others, is often found in adding a topping installation to the existing plant. This solution gives the best heat rate obtainable for the additional power and usually can be accomplished with a minimum of additional operating labor. This has been a common practice in industry for a number of years.

Looking at what is expected for the future, one word keeps coming to the forefront in the thoughts and in the conversation of power engineers. This word is "dependability." Without trying to compare the value of dependability to other types of power suppliers and users, the author gave some examples of what dependability means to a paper company.

Several mills were asked how much it costs per day if a major piece of their power equipment suffered an unanticipated, immediate shutdown. In contrast, the return, or dollars saved based on fuel costs, by an additional 1 per cent efficiency built into the unit, was calculated. The results are as follows:

Mill	*Cost Per Day Shutdown*	*Return Per Year 1% Efficiency Increase*
A	$41,000	$11,100
B	$33,270	$ 8,970
C	$11,070	$ 4,070

These figures indicate the very high cost of unscheduled outage time as compared with the effect of efficiency changes. This is not the whole story. In this type of mill, an unanticipated shutdown causes secondary troubles and it may be impossible to start much of the equipment until special precautions are taken to "unplug" critical agitators, pumps and the like. There is a steady deterioration of the quality of product in process as well. In addition, there are likely to be acute market problems.

The power engineer, faced with the pressures from management for continuous production due to costs and intangibles such as acute market problems, finds his attitude molded to give major emphasis to dependability in the selection of power equipment. A listing of the factors most likely to govern equipment selection in order of precedence is (1) dependability, (2) initial cost, (3) serviceability and (4) efficiency.

Carl E. Miller, Combustion Engineering, Inc., presented a boiler manufacturer's viewpoint. Engineering and economic factors, he felt, are of equal importance and are interdependent in sound planning for the future. Planning for the immediate operating requirements of a plant, as well as for changes in these requirements during the life of a plant, calls for careful attention to: (1) accurate estimate of steam requirements, (2) economy of design to meet these requirements and (3) flexibility of design. Mr. Miller then illustrated his points with several examples of boiler designs for suggested situations.

Automated Power Plants

In view of the mounting attention to the idea of automatic power plants the paper, "An Operating Report of the Monitored Sterlington Station," by **Donald Aswell,** Louisiana Power & Light Co., and **George Parmakian,** Riley Stoker Corp., was a valuable contribution.

At the Sterlington plant of the Louisiana Power & Light Co., equipment has been installed that should be capable of meeting part of the requirements of power plant automation. This is the general purpose solid state computer with a solid state analog to digital converter. As installed, the computer is doing only a portion of the functions that ultimately will be required for automation, but it should provide operating experience and confidence in part of the hardware that will be used.

The equipment scans 200 temperatures for abnormal conditions at a rate of five points per second and logs 100 other plant variables periodically, or on demand, for plant results or accounting purposes. Any scanned point will be printed in digital form and identified, if above or below a set value. The logged items are the usual points the operator records. All conventional multi-point recorders, temperature scanners, historical recorders and log sheets are replaced by this equipment.

During the scanning cycle each of the 200 temperatures is checked once every two minutes. Should an off normal temperature be detected, the value, time and point identification number will be printed on a high speed printer and an audible annunciator will sound an alarm and flash a light identifying the equipment in trouble. It is then up to the operator to make a decision for corrective action. Each succeeding scan cycle will continue to print the point value as long as it remains off normal. This gives the operator information for applying corrective action or shutting down the equipment in trouble.

The ADC system has notified the operator on several occasions when there were off normal temperatures in the plant, such as:

1. High temperatures on the boiler feed pump motor bearings due to plugging of the oil cooler.

2. High superheater tube metal temperature caused by adjustments made on the burner air directional vanes.

3. High seal water temperature on instrument air compressor and vacuum pump that developed when cooling water was shut off.

4. Turbine steam and metal temperature differentials that have been near the accepted limits caused by too rapid startup or too slow startup.

5. Oxygen analyzer cell low and high temperatures caused by failure of thermostat.

At various other times the ADC has permitted the operator to check temperatures that were suspected of being in trouble.

Accuracy of the ADC system has been checked often and consistently found to be within guarantee of ±0.1 per cent in so far as can be determined by the plant laboratory potentiometers. During preliminary unit heat balance checks the readings obtained with the ADC checked very accurately with readings taken by plant test personnel using potentiometers under the direction of the Ebasco Plant Betterment Department.

Since this equipment was new and of a more complex nature compared to the conventional power plant instrumentation, we had expected some difficulty in preparing the equipment for the guaranteed six month 99 per cent reliability test. Before the equipment was shipped it was decided the memory capacity should be doubled to 2048 words and that a new design power supply was needed to provide extra memory for control functions and a more reliable power supply. This equipment was added when available, approximately four months after initial operation. Prior to these replacements operation proceeded with an abbreviated program and the original power supply, neither of which affected the logging or scanning after the program was prepared.

Some of the problems with the ADC system to date have been:

1. Twice 110 volts ac was accidentally connected to some of the computer input terminals during initial check out, resulting in the burnout of several resistors and some transistors. All associated components were checked for partial failures and suspected bad parts were replaced.

2. The memory and power supply replacements necessitated a program change.

3. Failure of a "zener diode" in the analog to digital converter which caused several random errors and false alarms during two periods of approximately two weeks. Average daily false alarms were approximately three. The random error results in a false alarm which the operator immediately checks and calls for another read-out of the value. If the alarm is false, the second read-out gives a correct reading.

4. Heavy service on the tape punch caused an occasional error to appear on the logging typewriters. This required a redesign of the punch.

5. The alarm printer initially would clog the paper feed mechanism and required several days to properly adjust.

The advantages of centralized controls, the authors believe, have been proved in practice. The four-foot control panel for each unit is a refinement wholeheartedly endorsed by the power company and its design engineers. Close supervision of the turbine and boiler has become very important as the higher pressures and temperatures are reached. With the Boiler-Turbine-Generator control

board and the associated monitoring equipment one operator can completely guide the plant safely.

While this paper does not claim to present all the detailed problems involved in starting this unit the major troubles are listed and represent what may be considered the "usual" number of outages of a new unit. Yet, from each outage description it is obvious that the problems have all been manmade and each could have been prevented. In every case of trouble the equipment designed to safely shut the turbine or steam generator down functioned properly though sometimes maltreated.

After eight months of operation the general purpose solid state computer definitely appears to be the equipment needed for supplying the decision making ability in fully automatic power plant. To date all problems encountered have been solved, but several months further operation will be required before reliability is proved to be equal to the turbine, steam generator and other auxiliary equipment. Nevertheless, plans are in progress for the design of a fully automatic steam generating unit for the Louisiana Power & Light Co. (See COMBUSTION, April, p. 52).

Water Conditioning

A report was made at the 1957 American Power Conference of experiences with a 105,000-sq-ft condenser which had operated for somewhat over one year with 6061-T4 aluminum tubes on a unit at the Wisconsin Electric Power Co. The favorable economics and other considerations provoked sufficient interest to prompt a second report on the experiences gained in the two intervening years. This, **W. A. Pollock,** Wisconsin Electric Power Co., did with his paper "Aluminum Condenser Tubes - A Supplementary Report on a Plant Installation."

In general, Mr. Pollock reported, the early favorable experiences in Unit 3 continue. There has been but one tube failure from either steam or water erosion since the earlier report. The one failure was on the steam side where erosion occurred in a tube several feet down in a lane where stainless steel shielding had not been installed. The water side erosion due to sand on the inlet end is immeasurable with the dial gage. Occasionally it is necessary to replace a stainless steel shield due to one having come off or due to erosion or vibration occurring possibly because of a change in the flow pattern.

Fourteen tubes were plugged during the summer of 1958 after two were found leaking. These tubes are located in the air cooler section of the condenser, which consists of one vertical lane of tubes being covered with a steel envelope. Vapor and non-condensable gases enter at the bottom and flow upward over the tubes. The exit to the steam jet air ejectors is at the top. The tube bundle is divided by an open area about eighteen inches high halfway between the bottom and the top. The tubes which leaked were the bottom tubes of the upper bank. Thinning was found on the bottom half of the tubes in this row. The thinning was uniformly smooth and the wasted areas were covered with a thin black tightly adherent coating. A chemical and spectrographic examination of this material revealed both iron and aluminum oxides present. That the thinning was localized essentially in the bottom row was confirmed by tests with a Penetron thickness tester.

Unit 4 gave us our first experience with aluminum tubes in low pressure extraction heaters. After only two months of operation, leaks were found in heater 3, which is the low pressure heater on the unit which operates with a 6-psig steam pressure. A total of 25 tubes were plugged during three outages within a period of ten days. Tests revealed that an excessive pressure drop in subcooling section was causing flashing of condensate into steam and this resulted in erosion. Modifications to the heater reduced the pressure drop to an acceptable value and no more failures have occurred.

An inspection of this heater showed a considerable buildup of aluminum oxide on the steam side of the tubes. Iron oxide fouling on the inside of the tubes and on the heater drain pump has been greater on this unit than on any other. During the outage of the heater an attempt made to clean the outside surface of the tubes with water jets was unsuccessful but the inside of each tube was cleaned by means of air and water jet impingement from a nozzle which was extended into the tube as far as the bend of the tube. This very effectively improved the heat transfer rate to practically guarantee.

There is some evidence that both high-pressure and low-pressure extraction heater performance on units 3 and 4 with aluminum-tubed condensers is poorer than on units 1 and 2 with arsenical admiralty condenser tubes, due to fouling. Many heater dismantlings for modifications and repairs make it difficult to draw positive conclusions in this regard.

J. M. Wright and **W. T. Lindsay, Jr.,** Westinghouse Electric Corp., presented their paper on "A New Method for the Continuous Analysis of Dissolved Oxygen in Water." The reaction of dissolved oxygen with some other material to produce a measurable change in the electrical conductivity of a solution is the principle of several devices for the continuous determination of dissolved oxygen. The most convenient arrangement for measuring oxygen concentration in a flowing stream would be to employ a packed bed of solid reactant having the following as some of its desirable properties: (1) does not react with water, (2) is insoluble in water, (3) does not react with gaseous air or oxygen, or, at least, not violently, (4) reacts vary rapidly with dissolved oxygen in water, (5) does not react with other dissolved gases, (6) produces a highly soluble, strong electrolyte as the reaction product and (7) is readily available with a high degree of purity. Not many materials meet these requirements. Some solids, such as phosphorous, react moderately rapidly with dissolved oxygen, but also react with air quite violently. Others react with water, possess too high a solubility, or are unsuitable in some other way. In fact, the apparent absence of an ideal solid reactant has led to the development of devices employing gaseous reactants, with some additional complication of the required apparatus and restrictions on useful ranges of operating conditions.

The closest approach to the ideal solid for this purpose appears to be pure thallium metal. It is not attacked by water, while, in air, it is immediately covered with a layer of protective thallous oxide, stopping further oxidation.

Two types of prototype analyzers have been designed, constructed and tested.

By IGOR J. KARASSIK*
Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—VIII

QUESTION:

The deaerators which we have installed in our steam power plants for the last ten or twelve years were all provided with so-called "anti-flash baffling," that is an internal downcomer pipe extending from the deaerator section of the heater directly through the storage section and terminating at the pump suction outlet. This construction was intended to reduce the unfavorable effects of a sudden load drop on the performance of the boiler feed pumps. We understand that the use of this "anti-flash baffling" has now become a controversial issue and that some utilities are eliminating it from their specifications. Could you explain the reasons for this elimination?

ANSWER:

By way of explanation, I would like to point out that the "anti-flash" baffling of deaerators has always been a rather controversial item.

The effects of a sudden drop in turbine load on the conditions prevailing in a deaerator have been reasonably well understood for many years. It was noted that the resulting rapid reduction in deaerator pressure led to flashing in the deaerator storage compartment and in the boiler feed pump suction piping, frequently resulting in serious damage to the boiler feed pumps. The sequence of events and the analysis of cause and effect was not difficult to establish: a definite time lag intervened between the moment when the heater pressure (and the corresponding saturation temperature) was lowered and that when the now colder water finally reached the pump.

It was not until 1953 that accurate field tests were conducted in a central steam station with the purpose of accumulating the necessary data to establish a sound theoretical method for predicting the behaviour of the equipment in the "Fluid Handling Group" affected by such transient conditions.[1] As shown in Fig. 1, the equipment involved is the deaerating heater itself, the boiler feed pump, the suction piping and the condensate pump. Briefly, the violence of the flashing which follows a sudden load drop will depend upon the volume and temperature of the water stored in the heater, the feedwater flow delivered by the boiler feed pump immediately following the load drop, the volume of the suction piping between heater and feed pump and the rate at which cold condensate is admitted into the heater at this moment.

But even prior to 1953, efforts of power plant engineers and equipment designers were directed towards eliminating or at least alleviating the ill effects of these transient conditions.

One of these efforts culminated in the development of the so-called "Anti-flash Baffling" for the deaerating heater, a protective solution which became quite popular between 1943 and 1955. Recently, however, the efficacy of this solution has come to be seriously questioned and it is with this efficacy that we shall deal presently.

Typical arrangements of anti-flash baffling are illustrated on Figs. 2, 3 and 4. It will be seen that baffling is provided immediately below the deaerating section, along with internal piping, so as to conduct feedwater directly from the heating and deaerating element to the outlet nozzle and on to the suction piping. An annular clearance space is provided at the bottom of the storage space between the downcomer pipe and the outlet nozzle, so

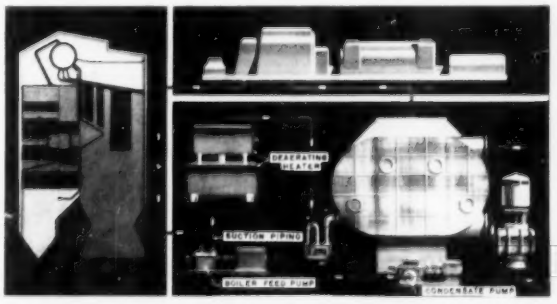

Fig. 1—Equipment in the fluid handling group affected by transient conditions caused by sudden load drop

* Consulting Engineer and Manager of Planning, Harrison Div.

[1] See "Centrifugal Boiler Feed Pumps under Transient Conditions," by Karassik, Bosworth and Elston, presented at ASME meeting Oct. 5-7, 1953 at Rochester, Paper No. 53-F-32. Worthington reprint No. RP 702.

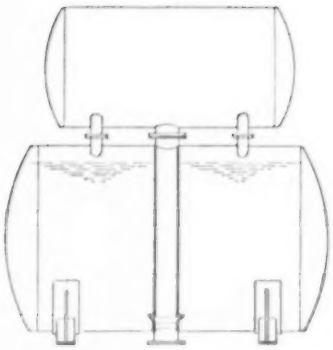

FIG-2.

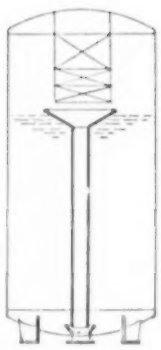

FIG-3

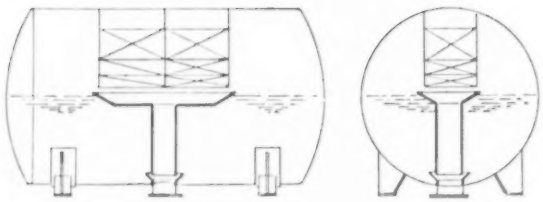

FIG-4

Figs. 2, 3, 4—Typical arrangements of anti-flash baffling

that an excess of deaerated water over and above the boiler feed pump demand can spill into the storage space. Conversely, an excess in demand over the deaerated flow is made up from the storage space through this annular clearance space.

In order to appreciate the mechanics of anti-flash baffling, an analysis of the events taking place in the heater is necessary. Since water leaving the heating element is always at a temperature corresponding to the pressure in the steam space in the heater during a load drop it will be cooler than water taken from the bottom of the storage compartment. This temperature difference will amount to the change in saturation temperature corresponding to a pressure equal to the height of water in the storage compartment. Therefore, with anti-flash baffling, when water leaves the heater outlet nozzle during a load drop, instead of being at saturated condition, it will be at a pressure above its vapor pressure by an amount equal to the static head of water up to the surface, minus the amount of pressure which the heater has lost during the time it has taken this water to travel from the surface to the outlet nozzle.

The net effect of anti-flash baffling is therefore equivalent to elevating the heater by the amount of the static head between the water surface in the storage space and the outlet nozzle. The beneficial effect is decreased slightly by the fact that the time lag is increased by the amount of time it takes the feedwater to travel through the internal downcomer pipe.

However, the most important factor in the evaluation of any advantages accruing from anti-flash baffling is that this effect will only begin to be realized when feedwater which was just leaving the heater at the instant the load drop began, reaches the pump. And yet, both a theoretical analysis of the problem and field test verification of the theory indicate that the most critical period from the point of view of NPSH reduction occurs at the end of the residence time in the suction piping, in other words at the moment when the effect of anti-flash baffling will start manifesting itself. From that moment on, even though the pressure in the heater may still continue to drop, the feedwater entering the pump suction will be progressively cooler—and therefore will have a progressively lower vapor pressure. Thus, the poorest suction conditions caused by a sudden drop in main turbine load will prevail prior to the time when anti-flash baffling can be of any possible help.

While this theoretical analysis was difficult to refute, it was felt that an experimental verification of the sequence of events which follow a sudden load drop in a deaerating heater provided with anti-flash baffling would be of invaluable assistance. Consequently, such a verification was incorporated into the field tests which formed the basis of the ASME paper referred to.[1]

These tests were carried out on a 100,000 kw unit installed at the Moss Landing Steam Plant of the Pacific Gas & Electric Co. in September 1953. The rapidity with which changes in pressures, flows and temperatures take place during transient conditions made direct observation of data impossible. But the operating mechanism of the necessary recording apparatus was modified so as to greatly magnify the time scale. A standard 24-hr chart was transformed into a 24-min. chart and the changes which took place after sudden load drops could be read and analyzed quite readily.

A number of tests were carried out with varying load drops and the results utilized in formulating a comprehensive theory of the behaviour of the Fluid Handling Group during transient conditions. The particular test which interests us at this moment is that in which a load reduction from 117,500 kw to 28,000 kw took place in 10.5 sec. Fig. 5 shows the effect of this load drop on the suction conditions at one of the boiler feed pumps serving this 100,000 kw unit. Readings from the recording charts start one minute prior to the load change, so that "zero" time corresponds to the load reduction.

The changes in the value of required NPSH reflect the variation in boiler feedwater demand caused by the action of the feedwater regulator. In turn, changes in available NPSH reflect the behaviour of the deaerating heater (which was provided with anti-flash baffling) and the effect of the time lag of the colder feedwater in its passage through the suction piping.

The data obtained during this test demonstrate the validity of the analysis presented above and of the conclusion that anti-flash baffling is of negligible value—if any—in protecting boiler feed pumps from cavitation following a sudden load drop. If the installation is such that trouble will develop at the most critical moment, the anti-flash baffling will not be effective in warding off this trouble early enough. If the boiler feed pump can get through that difficult moment, there is hardly the need for further help. We can therefore conclude that relying on the protection of anti-flash baffling is pretty much the case of "too little and too late."

We may ask, however, what of the several installations

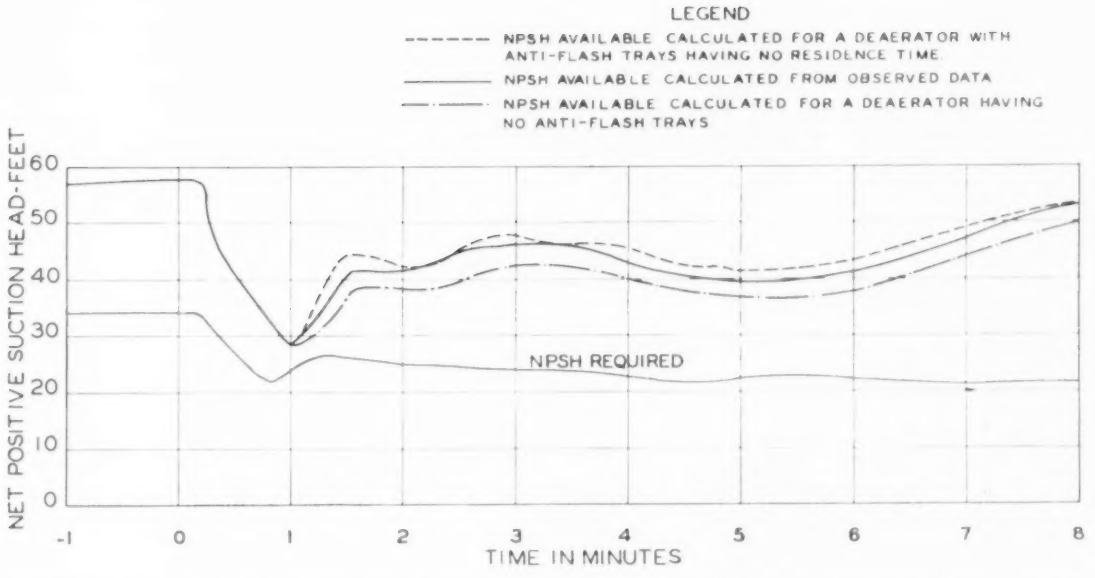

Fig. 5—NPSH at boiler feed pump for deaerator with and without anti-flash trays. (Load reduction from 117.5 mw to 28 mw.) Moss Landing Steam Plant, Pacific Gas and Electric Co.

which are reputed to have cured the ill-effects of sudden load drops by incorporating anti-flash baffling in the deaerating heaters? In some of these cases, the modification to anti-flash baffling took place after initial installation and troubles experienced before the change were reported to have been eliminated. Do these cases vitiate the truth of this analysis?

It is difficult to answer this question unqualifiedly, for no other reason that no field tests exist of such installations in which readings were taken on a time scale magnified sufficiently to make the true picture of the events clear enough. Several suppositions, however, can be made as to the reason for the absence of serious difficulties in these installations. One of the most plausible of these assumes that the presence of anti-flash baffling leads to a stagnation of the feedwater in the storage space, all the feedwater coming to the feed pump through the internal downcomer. This, in turn, causes an appreciable sub-cooling in the storage space and a certain amount of stratification, with the coldest water settling and stagnating in the bottom layers. A sudden load drop may be followed by an increased demand of feedwater (because of boiler drum shrinkage) and a simultaneous reduction of cold condensate delivery to the heating element of the heater. The difference in demand is immediately made up from the colder bottom layers, with this cold feedwater entering the suction piping through the annular clearance at the bottom of the heater. The subsequent events can vary. This colder water may act to quickly quench any flashing which takes place in the suction piping. If, however, this action is not rapid enough, the pump may go through some partial flashing of short duration and its operation is more rapidly restored to normal than if anti-flash baffling were omitted, since the quenching water is colder by virtue of the sub-cooling.

This stratification and stagnation may not always be a blessing, however. There is mounting evidence, as a matter of fact, that it can act to aggravate the ill-effects of a sudden load drop in some cases. If the feedwater in the storage space is thoroughly mixed, and all at a uniform temperature approximately equivalent to the heater saturation temperature, any drop in heater pressure will be accompanied by violent flashing throughout the storage space. The steam thus released will immediately act to retard and slow down the rate of pressure decay in the heater. On the other hand, if the feedwater in the storage space is at a temperature materially below saturation temperature, an appreciable pressure drop can take place in the heater before any flashing takes place in the storage space and therefore before the pressure reduction is retarded.

For this reason, a number of utilities prefer to avoid any type of baffling which could lead to temperature stratification in the storage space. Instead, an effort is made to facilitate violent mixing of this feedwater at all times, so that this mixing can provide some protection during load drops.

In summarizing the theoretical and experimental evidence gathered up to the present, I now reverse a position which I held from 1944 until 1952 and recommend against the use of anti-flash baffling as a protection against transient conditions. If an analysis of a proposed or existing installation indicates that critical conditions may arise, there are a number of other solutions, more effective and more assured to eliminate the hazards created by sudden drops in turbine load.

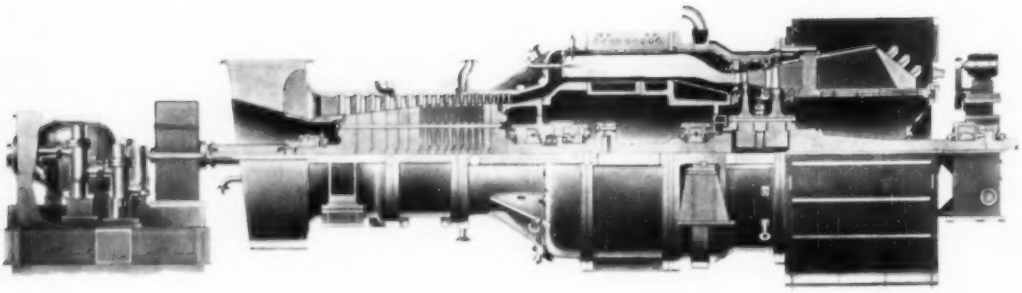

Fig. 1—Cross-section of a General Electric simple cycle, one-shaft gas turbine, rated 16,500 kw

Design Concepts of a Low Cost Gas Turbine Generating Plant for Peak Load Service*

BY A. O. WHITE, R. J. CARPENTER and W. D. MARSH

General Electric Co.

The results of a design study to develop a gas turbine and associated plant for electric utility peak load service with both turbine and plant design detail and specifications worked out to the point when prospective users may obtain price quotations for all material and labor necessary to construct the complete plant on any suitable site, are given here. Such quotations have been secured in two specific utility locations, with the result that plant cost is rather accurately and reliably known.

Characteristics of Peak Load Generation

THE principles of application of peaking generation have been discussed previously before this conference (1, 2).† The prime characteristic of peaking generation is low investment cost. High reliability (low forced outage rate) is next in importance. Least important are those costs which are proportional to operating hours: fuel and maintenance. The gas turbine is unique in that by a moderate sacrifice of fuel and maintenance costs it is possible to realize substantial savings in plant investment cost.

Gas Turbine Characteristics

The gas turbine has other characteristics which enhance its application to peaking service:

1. **Automatic Operation.** Automation of generating stations is a reality in several unattended remotely controlled gas turbine installations. Reliability of the gas turbine control panel components is proved by over 150 other semi-automatically controlled units. The saving in operating labor is substantial and removes the major incentive to maximum unit size.

2. **Moderate Unit Size.** Since low investment cost and essentially zero operating labor cost can both be achieved with gas turbines in the 20-30 mw size range, there is little argument for peaking units of the larger sizes customary in base load steam generation. On the other hand, excessively small sizes result in such large numbers of units that system operating and maintenance schedules become unmanageable. It is now recognized that units of 15-50 mw can provide adequate peaking capacity on even large systems with reasonable numbers of units, and with substantial savings in bulk transmission investment.

3. **Flexibility of Location.** These bulk transmission savings are possible because the gas turbine station can be located without regard to cooling water or continuous fuel supply. This means that in many systems the station will be tied into an existing subtransmission substation. If residential areas are close by, effective silencing of station noise can be provided at reasonable cost. High combustion efficiency and extremely high excess air in the turbine stack eliminate air pollution problems in nearly all cases.

4. **Quick Startup.** It requires 20 to 30 min to start a gas turbine station and have it on the line at full load. This can mean a major reduction in standby and excess spinning reserve costs when contrasted with the several hours required for steam-electric unit startup and load-

* Presented before the American Power Conference, Chicago, Ill., March 31-April 12, 1959.

† Figures in parenthesis refer to the references at the end of the paper.

ing. There is, however, no justification for quick startup as a *substitute* for spinning reserve. Even one- or two-minute startup (possible with reciprocating engines) cannot replace true spinning capacity, unless present standards of frequency and voltage quality are to be seriously compromised.

5. **Extra Capacity at Low Ambient Temperatures.** Many utilities in the middle and northern parts of the country have recently begun to experience summer peak loads of magnitude comparable to their winter peaks. This "double peak" has serious implications with respect to maintenance schedules. The only seasons remaining for planned maintenance outages are spring and fall. In this situation, the increased capability of gas turbine stations in cool weather is fully useable, by providing additional capacity while other units are out of service.

6. **Flexibility of Capacity Additions.** The moderate size of gas turbine units permits close fitting of capacity additions to load requirements. One or more peaking units may be installed in one year to meet load growth and defer a much larger base load steam unit. It is not necessary to depart from established optimum steam unit size to economically add moderate size peaking gas turbines.

Gas Turbine Design Concepts

The gas turbine is a complete power station in itself with few auxiliaries; but correspondingly, factors which affect the cost per kw of the gas turbine itself, have a direct and major affect on the total cost per kw of the installation.

The cost of the gas turbine is a function of its physical size and complexity and the relative amount of high temperature alloys, with a high cost per pound, that must be used in its construction. While all modern gas turbines operate basically on the so-called constant pressure cycle, there are a number of variations from the simple open cycle machines (3) that can be used to improve the efficiency and reduce the air flow required per kw output, i.e., Air Rate. These variations which can include intercooling, regeneration and reheat in various combinations all add to the complexity of the plant and to the pieces of equipment comprising the unit.

A reduction in Air Rate, of course, results in a smaller physical size machine, but if at the same time there is an increase in the number of pieces of equipment to furnish the required output, the overall cost may be more rather than less. Similarly, an improvement in efficiency, with resulting reduction in the quantity of fuel burnt will save on the cost of the fuel handling equipment, but if again, it is accompanied by increased complexity, the overall cost will probably increase.

With whatever cycle is employed, however, an increase in the top temperature of the cycle, i.e., the firing temperature, will always reduce the Air Rate and improve the efficiency. It follows then, that for minimum cost the maximum temperature attainable, without an unbalancing increase in the cost of the high temperature materials in the gas path, should be employed. For any cycle selected there is an optimum pressure ratio for every firing temperature, but since performance is not critically dependent upon pressure ratio, increasing the firing temperature in any given cycle is well worth while.

Gas turbines are relatively simple prime movers and lend themselves readily to high specific outputs, which is the basis for their universal application in high performance aircraft. The design criteria for an aircraft power plant, low specific weight and high output per unit of frontal area, do not apply to units for land application, particularly central station units. Weight in itself is of relatively little importance, and reliability, long life and low cost per unit of output with commensurate efficiencies are the prime objectives. Gas turbines for peak load applications, such as we are considering, must, therefore, be designed on a basis entirely different from aircraft gas turbines and the resulting units are very different in size, appearance and methods of construction. This is not to say that the manufacturers have not profited by the experiences and developments of the jet engine manufacturers (it should be noted that two of the largest gas turbine builders make both types of gas turbines); but rather that they have had to develop criteria and designs more in line with large steam turbine practice (again the same manufacturers are the largest builders of large central station steam turbines).

A cross-section of a typical gas turbine suitable for peak load operation in central station service, and rated 20,500 kw with 80 F inlet temperature at 1000 ft altitude is shown in Fig. 1. Detailed descriptions of similar units have been published previously (4, 5), and only a brief description is included here primarily to make some of our premises clearer.

The cross-section is of a simple cycle, single shaft gas turbine; that is, it operates on an open cycle without intercooling, reheat or regeneration, which based on the considerations discussed above, we believe to be the type of gas turbine most suitable for peak load applications. The 16 stage compressor is at the left, the two-stage turbine at the right and the 16 combustion chambers in the annular space in between. Air enters the compressor at the left, is compressed, passes through the combustion system where the fuel is burnt, produces power in the turbine and exhausts to the stack on the right.

The compressor casing, the combustion system wrappers and the turbine shell are built up from substantial castings or fabrications, and when bolted together form a rigid backbone for the machine to maintain alignment of the bearings that support the rotor. Stresses in the casings are low, and temperatures are moderate, since they are protected in the high temperature regions by the internal insulation shown and the use of cooling air where necessary. The combustion gases are confined to the light, stainless steel gas path, which is supported in the casings with freedom to accommodate the radial and axial expansions that take place on starting or change of load.

The rotors are built up from individual steel forgings, held together by through bolts. The stresses in the wheels and shafts, and the corresponding factors of safety are equivalent to those in large steam turbine rotors and the non-destructive testing of the components follows established steam turbine practice. In addition the turbine wheels because of the size of the forgings involved, are put through a special stress relief anneal, "autofrettage" or stretching of the bore and a cold spin test to assure their quality and reliability in service.

The high temperature parts comprise only the combustion liners and transition pieces, the first and second stage nozzles and the turbine buckets and shrouds since all other components are either insulated or air cooled. Their allowable stresses are set to give adequate factors of

safety based on the rupture strengths at the operating temperatures of the material used, over a sufficient number of hours to provide trouble-free service for the operating life of the unit. In the normal design of commercial gas turbine units the materials and stresses at the maximum design operating temperatures are selected to give an operating life equal to modern large steam turbines. Thus it is expected that only normal maintenance will be required during the life of the machine.

Uprating of Gas Turbine Units

The gas turbine generator units which are proposed for peak load service were originally designed for continuous operation at their rating in central station base load service. On this basis the firing temperature was set at 1450 F and materials and operating stresses selected accordingly. As a result of the considerations outlined at the beginning of this paper, it was decided that low installed cost was the most important consideration for peak load application, and that since the number of operating hours per year would be limited by the very nature of the application, compromises particularly in maintenance cost per operating hour could be made to obtain low installed cost.

In considering the factors involved in lowering the cost per kw of the gas turbine itself, it appeared that the existing simple-cycle, single-shaft design described offered the best possibility of achieving a low cost per kw if its rating could be increased without a commensurate increase in cost. Since the speed, and corresponding air flow is fixed by the 60 cycle system frequency, and the air flow had already been set at the maximum within the design limitations of the compressor, the only practical possibility lay in increasing the firing temperature of the unit.

In a simple open cycle unit the capacity can be increased approximately 8 per cent for each 50 F increase in firing temperature. Thus this offers attractive possibilities if the temperature could be raised as high as 1600 F. What is the effect on the gas turbine and its operation?

Since the speed is constant, the centrifugal stresses are not increased, and with approximately $^2/_3$ the turbine output going to drive the compressor, a 20 per cent increase in net output does not significantly increase bucket bending, shaft torsion or other mechanical stresses. However the operating temperature of the hot gas path parts are increased. In the case of the stationary parts the stresses are already low enough that the increased temperature can be accepted with little change in material or design; but with the expectation of some increase in maintenance.

In the case of the turbine buckets, most of the stresses are already at or near the limit established by the rupture strength criteria, i.e., relation of rupture strength to time and temperature mentioned above. Thus either the materials or the criteria must be changed or both. In view of the limited duration of peak loads on a system, and the corresponding limited number of operating hours per year, it is considered that the total operating hours, at least at maximum rating and temperatures, during the expected life of the machine will also be limited. It is thus appropriate to reduce the number of hours at which the rupture strength is selected, and thus increase the allowable temperature at which the normal factors of safety are obtained at the working stress. This is best illustrated by Fig. 2, in which relative time to rupture in per cent is plotted against firing temperature, as a representative parameter, at constant stress.

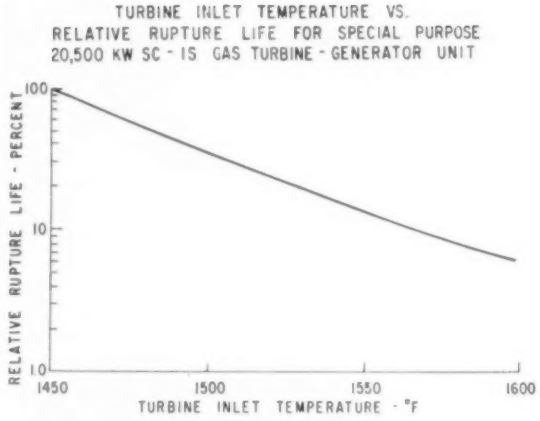

Fig. 2—In view of the limited operating hours at maximum rating and temperatures the above rupture curve of time against temperature is valuable information

For the maximum utilization of material it turned out to be advisable to change bucket material as the root centrifugal stresses in the vane sections were limiting. By proper selection of material it is possible to achieve more uniform factors of safety at the maximum operating temperature and so achieve a well balanced design with the minimum cost per kw for the gas turbine. While the maintenance cost will be increased, the increase will be limited to parts in the hot gas path which can be considered expendable and replaceable. The overall useful calendar life of the machine will not be affected.

This whole approach is conservative since it presupposes that whenever the machine is operated it will run at maximum load with full 1600 F firing temperature. It is unlikely that peak load units will run this way so that the parts will operate part of the time at lower temperatures with a corresponding increase in the allowable stresses or factors of safety and an accompanying reduction in maintenance costs.

The net result of this approach is to provide a power generating unit with a lost cost per kw, reasonable maintenance costs, and as will be discussed further, low installation costs to make an economically favorable peak load station.

Gas Turbine Station Layout

The gas turbine as a self-contained prime mover, lends itself to several different installation arrangement possibilities. Primary considerations necessary to low cost installation are short runs of ductwork, concentration of unit operation on one level and a close physical relationship between the main unit and its auxiliaries. Individual installation requirements will vary between different site locations, relative to foundation design, source of cooling water, fuel supply, and the electrical tie-in with existing systems. These basic design conditions have little or no effect on station arrangement.

If it is found that adequate space in an existing building is available, it may be that the savings of new building materials plus the availability of existing handling facilities and use of existing services makes the most

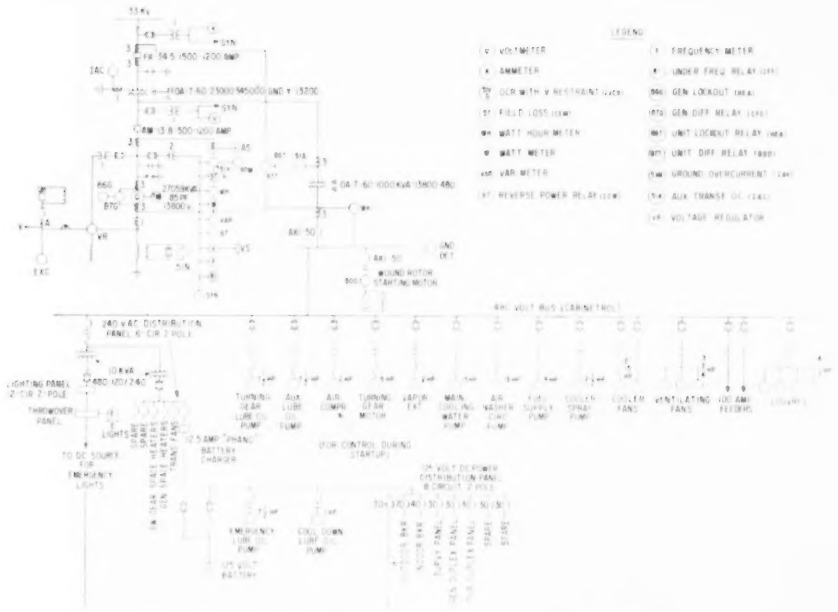

Fig. 3—Single line diagram of a typical gas turbine generating station

economical installation. This is sometimes true; but before such a decision is made, it is wise to carefully analyze the cost of connecting ductwork, extra foundation height to match existing operating platforms, re-routing of existing pipe lines, and electrical interconnections necessary to tie the new unit into the overall system, for the specific installation.

Foundation requirements vary in accordance with ground loading. A simple reinforced mat poured below grade with short supports designed to suit installation requirements of the turbine generating unit is usually adequate. This design is consistent with grade level operation and the topside type of air and exhaust gas ductwork connections normally found in low cost plant arrangements.

Careful consideration must be given to the arrangement of ductwork when initially planning the unit's installation. Long runs of exhaust gas duct require extra stainless steel bellows type expansion joints together with the required guides and stops, which are necessary to assure that each joint will take its full share of the overall expansion and be restrained from movement in the wrong direction. These extra joints and ductwork material can quickly build up the cost of unit installation. Recent studies show that when the air intake is taken from the side of the building and the unit exhausts out the side, the most economical design is achieved. This arrangement eliminates ductwork running parallel to the unit, thus leaving the entire length of the turbine-generator accessible to a crane hook for maintenance work.

The gas turbine, requiring so few auxiliaries to complete its installation, will reduce interconnecting piping appreciably over the corresponding steam cycle. Major piping requirements are shipped as an integral part of the gas turbine. Thus, only cooling water, fuel, and CO_2 fire protection piping is necessary to complete the basic power cycle in the station.

Electrical apparatus necessary for outgoing power and generator protection is similar to the conventional steam plant (Fig. 5). The auxiliary control apparatus is limited to the few low voltage, nominal horsepower turbine and station auxiliaries. The physical location within the plant of this apparatus will determine the length of interconnecting cable and conduits which will affect the cost of installation. This apparatus would be concentrated in a centralized control room if the plant is to be manned. If the installation is designed for remote control, the panels and electrical apparatus may be spotted around the main generating unit in positions which will reduce interconnecting material requirements to a minimum.

Factors Contributing to Low Cost

There are many opportunities to reduce installation costs resulting from the integrated design of the gas turbine and its simple foundation. Space requirements are much less than other generating units of equal capacity. This will permit the use of inexpensive building designs to house the equipment.

Building enclosures must be designed to satisfy local conditions and standards. Grade level operation and grade supported auxiliaries can simplify the building design. Several recent installations have been housed in conventional structural steel frame buildings with corrugated protected metal siding and roofing. The windows, doors and ventilators are of standard commercial manufacture. This type of construction is low in cost, but gives full protection to equipment and personnel. In areas where climatic conditions permit, the semi-outdoor design should be considered. This will include only a walk-in enclosure around the gas turbine, plus weather protection for the exciter, control panels and electrical apparatus, thus reducing installation costs accordingly.

Gas turbine auxiliary requirements will vary with selected site locations, local ordinances, incoming services

and climatic conditions. The standard installation requires an air intake filter and silencer, ductwork, exhaust stack, incoming supply of fuel and cooling water together with necessary controls and electrical apparatus. Additional equipment may be installed to increase output, satisfy pressure requirements of incoming services or to accommodate unusual local conditions. The advantages of including additional optional items should be evaluated against the gain in unit power output.

Design engineering and erection are two of the major cost items of any power generating plant. The simplicity of the gas turbine plant will reduce these costs.

The Final Design

Figs. No. 3 and 4 portray a low cost station arrangement incorporating a 20,500-kw gas turbine-generator with auxiliaries as required for a specific installation. The plant was designed to satisfy peak loads on a large system and for remote operation.

The gas turbine is the simple cycle, single shaft, distillate oil burning unit shown in Fig. 1. The turbine rated is 20,500 kw, direct-connected to an air cooled generator rated 27,059 kva, 0.85 power factor and suitable for a cooling water of 95 F or lower at rated output.

The station layout is consistent with the concepts given for a low cost installation. The equipment requires an area of approximately 2700 sq ft, including 500 sq ft of laydown space for maintenance. This is comparable to approximately 7500 sq ft required for a conventional steam turbine-generating plant of the same rating. The unit is served by an overhead crane running parallel with the generating set. The design provides for the installation of a future unit, located along side and parallel to the initial installation with the intake air and exhaust gas ductwork together with outdoor auxiliaries of opposite-hand. Otherwise the arrangement would be duplicated. Alternatively units may be in line to extend the station.

Auxiliaries in addition to the normal requirements were justified in this specific design to increase power output during summer peak demand and to conserve cooling water. These auxiliaries include an evaporative air cooler to lower intake air temperature during high ambient periods with resultant increase in capability under these conditions. To reduce cooling water requirements a closed cooling water heat exchanger system was added. This system consists of an evaporative cooler together with the necessary spray pumps, circulating water pumps and associated controls. The major auxiliaries are mounted outside the building on independent footings, reducing building requirements accordingly. Controls and small motor driven pumps which require protection are located within the building.

Electrical apparatus and control panels are placed in logical sequence at the generator end of the building with adequate space provided for maintenance. Maximum advantage of the factory assembled and wired metal-clad units is incorporated in the selection and location of this apparatus, thereby reducing installation material and erection costs.

Conclusions

The approach described has resulted in a low cost generating station design that it applicable to a wide variety of systems and locations. We believe the concept of a peak load station of low installed cost that can be readily installed where most needed on the system is sound and an uprated gas turbine installation is the ideal solution.

Actual costs are, of course, difficult to predict, as they depend so much on labor costs in the area and details of the particular installation, including location. The best way to evaluate the gains that can be realized is to express them in relation to a conventional steam plant. As mentioned above the area required is only about $^1/_5$ that of an equivalent steam plant and the savings in installed cost should be from 15 to 30%.

Such savings, with the added possibility of deferring the large investment required for a large base load unit offer attractive possibilities in meeting the peak load requirements of most generating systems. A careful consideration and evaluation of all the factors in any particular situation are required, but the corresponding savings can be substantial and should not be overlooked.

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(4) "Design Features of New Large Gas Turbines for Power Generation," by A. O. White, AIEE paper No. 57-968. Presented by V. P. Purcell at the 1957 AIEE Pacific General Meeting, Pasco, Wash., Aug. 28, 30, 1957.

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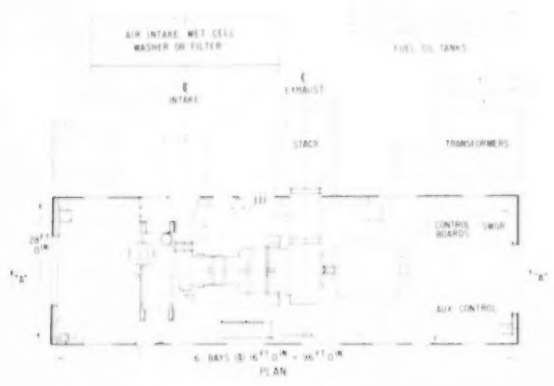

Fig. 4—Plan view of a typical gas turbine generating station

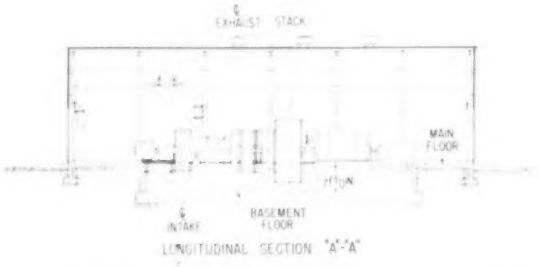

Fig. 5—Longitudinal section of a typical gas turbine generating station

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Somehow, you just expect Green fans to give years of trouble-free operation.

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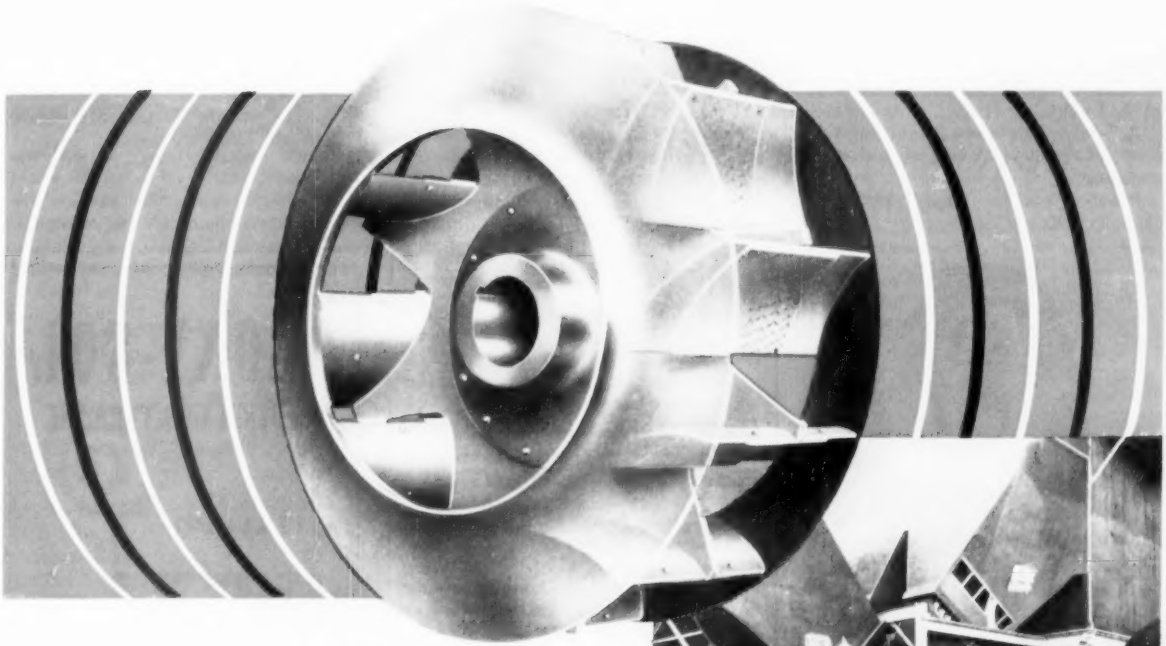

The Green RG is a centrifugal fan whose blades are forward curved and backwardly inclined with blade tips approaching a radius of the wheel. Design achieves a streamlined air passage with a minimum of turbulence.

This is the induced draft Green RG Fan installation at the Possum Point Power Station. ¼" housing and inlet boxes. ½" scroll liners. Diamond checkered floor plate blade liners. Air-cooled, self-aligning sleeve bearings. 600 HP, 880 RPM motors.

Green

THE GREEN FUEL ECONOMIZER CO., INC. **BEACON 3, NEW YORK**

Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion Ltd., London, W.C. 1)

Power Station Coal Handling. A. Szold. *Electr. Rev.* 1959, **164** (Jan. 16) 95–101.

Recent practice at power stations of the C.E.G.B. is described. Various types of wagon tipplers, hopper wagons and dischargers, arrangement of systems, traveling paddle feeders, dust extraction, tippler hoppers, transfer hoppers, ground hoppers, crushers, pressure breakers and coal samplers are illustrated.

Hydraulic Transport of Coal. Y. Otsubo. *J. Fuel Soc.* 1957, **36** (Dec.) 913–24 (In Japanese, English summary).

Tests carried out on the hydraulic transport of coal are described; successful results obtained are discussed.

From C.E.G.B. Digest 1959, **11** (Jan. 31) 262.

Moving Solid Particles with Fluids. E. P. Ballinger. *Battelle Techn. Rev.* 1958, **7** (Oct.) 3–7.

A brief, comprehensive account is given of the general field of hydraulic transport.

From *C.E.G.B. Digest* 1959, **11** (Jan. 31) 263.

Solves wet salt storage problems. New Morton LEVETROL Read all about it next month.

Heat Cycles and Transmission

Heat Transfer and Pressure Drop of Air in Forced Convection Across Triangular Pitch Banks of Finned Tubes. D. J. Ward and E. H. Young. *A.I. Chem. E. Preprint* No. 26 1958 (Aug.) 15pp.

In view of the increasing use of air cooled condensers, heat transfer and pressure drop investigations have been made on high and low finned tube assemblies and the data correlated by two equations. Further data are required for thicker fins and large fin clearances and different tube arrangements.

Steam Generation and Power Production

Construction of Boilers from Prefabricated Parts. E. Weissgerber. *Mitt. V.G.B.* No. 57 1958 (Dec.) 381–92 (In German).

Examples of prefabrication of boiler parts are illustrated, such as economizers, boiler frames, distributors, headers, superheater and reheater parts, furnace walls, roofs and hoppers, cyclone furnaces, burner assemblies, grates and tubular air preheaters.

Water-Tube Boiler Explosions Since 1945. S. D. Scorer. *Mech. World* 1959, **139** (Jan.) 13–14.

Twelve explosions of water-tube boilers have been reported since 1945. The causes of each are described and the lessons to be learned are pointed out.

Furnaces and Combustion

Basic Principles of Combustion—Model Research. A. A. Putnam and E. W. Ungar. *A.S.M.E. Preprint* No. 58-A-73 (1958) (Dec.) 6pp.

The basic assumptions upon which cold flow modelling of combustion systems is carried out, the application of modelling to various combustion problems and the type of results that should be expected from the application of modelling techniques are discussed.

From *authors' abstract*.

Combustion Investigations with High Moisture Brown Coals. H. R. Brown. *C.S.I.R.O. Coal Res. Sect. Ref.* M.148 1958 (Dec.) 19pp.

Combustion pot tests simulating both overfeed and underfeed combustion of brown coals with moisture contents from 15–62 per cent are reported, in which the ignition and combustion characteristics of these coals were studied. It has been shown by these tests that brown coal with more than 60 per cent moisture can be efficiently burned on traveling and spreader stoker grates if 70–80 per cent of the combustion air is provided as primary air. Preheating the air improves the efficiency but is not essential.

Effect of Ash and Volatile Matter in Fuel on Incomplete Combustion. S. A. Tager. *Teploenergetika* 1958, **5** (Oct.) 10–16 (In Russian).

Curves are plotted illustrating the rate of fuel burnup, and a new method is presented for calculating the losses arising from incomplete combustion of fuel. The quantitative effect of ash and volatiles in fuel on incomplete combustion in the case of bedded and pulverized fuels respectively is considered.

From *C.E.G.B. Digest* 1959, **11** (Jan. 31) 266.

Water-Side Corrosion and Water Treatment

Hydrazine Assures Effective Deaeration. J. R. Coursault. *Pwr. Engng.* 1958, **62** (Dec.) 84–5.

Recent investigations make it appear likely that hydrazine does not react directly with the oxygen dissolved in the feedwater at tempera-

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• Oxygen-
• Scavenger
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tures below 400 F, but that it undergoes a heterogeneous surface reaction: $6FeO_3 + N_2H_4 = 4Fe_3O_4 + N_2 + 2H_2O$ and $4Fe_3O_4 + O_2 = 6Fe_2O_3$. Hydrazine also reduces deposits in the boiler and aids in quick start-up.

Increase of Efficency of Steam Power Plants by Gas Turbines. Nebojsa Gasparovic. *VDI-Z.* 1959, **101** (Jan. 1) 9–13 (In German).

The various possibilities of improving the output of steam power plants by the incorporation of a gas turbine are discussed.

Evaluation of Supercritical Pressure Steam Plants Based Upon the First-Time Operating Experience at Philo. P. Sporn and S. N. Fiala. *World Pwr Conf. Canadian Sect. Meet.* Montreal Paper IIIB$_5$ 5 1958 (Sept.) 14pp.

Comparisons are made between planned and actual performance of the water control and treatment system, major control systems, steam generator, turbine and generator, bypass system, turbine and superheater bypass, flash tanks and steam dump piping, feed pumps, high pressure piping and efficiency. Whilst operation in general was satisfactory, minor adjustments were found necessary, such as to limit the rate of heating of austenitic parts beyond the steam generator to 200 F/h, redesigning of pump seals to reduce the power required by the feed pumps and the use of stellite in valves showing severe erosion. The plant net heating rate was 8923 Btu/kwh instead of 8759 btu/kwh, the difference being due to the higher power required by the feed pumps and the higher speeds required by the recirculating gas fans. The application of the experience gained with the Philo plant to the two 450-mw units under construction is discussed.

Fully Automatic Medium Pressure Steam Power Station, Dalmine, Italy. E. von Rütte. *Energie* 1958, **10** (Dec.) 510–4 (In German).

The power station of Dalmine S.p.A. for the production of seamless steel tubes contains three Sulzer natural circulation boilers, two rated at 93 klb/h and one at 150 klb/h at 630 psi and 905 F and two 9-mw and one 15-mw turbogenerators. The boilers are natural gas and/or oil fired; if oil fired, magnesium oxide is injected at the burners to neutralize any SO_3 and the tubular air preheaters are washed regularly. The thermal efficiency with both fuels is 90–92%. Control is by the oil-hydraulic system developed by Sulzer which keeps steam pressure and temperature within narrow limits despite frequent heavy load fluctuations.

Union Electric. M. F. Dallen. *Heat Engng.* 1958, **33** (Sept.–Oct.) 150–3.

Unit No. 3 at the Meramec station of Union Electric Co., is a twin furnace dual circulation-type boiler rated at 1850 klb/h at 2450 psi and 1010/1010 F. Both furnaces are exactly alike and each contains a radiant superheater, division wall, boiler section and burner protection tube circuits. One convection pass contains the final superheater, the other the reheater. Steam temperature is controlled by condenser-type heat exchangers in the radiant superheater header whilst reheated steam temperature is controlled by the firing rate in the furnace containing the reheater. Coal pulverized to 70 per cent through 200 mesh in three ball mills, each of 84,000 lb/h capacity, is fired through 24 intervane burners, 12 to each side and arranged in three rows of four. Unit No. 4 to be in operation by 1961 will have a capacity of 2310 klb/h with the same steam parameters but a single furnace.

Thermal Power for New Zealand. Anon. *Engng Boil. Ho. Rev.* 1959, **74** (Jan.) 4–11.

Mercer power station will, when completed, contain six 30-mw units. Each semi-outdoor boiler is rated at 300 klb/h at 600 psi at 850 F and equipped with three mills and three primary air fans. Six burners are installed in the furnace roof, the economizer in the open pass above the superheater and the tubular air preheater between the coal bunker and the chimney and cleaned by steel shot. Open-cast coal is obtained from the Maramarua mine by aerial ropeway and because of its high moisture content of up to 25 per cent, provision is made to preheat the air up to 700 F. Additional coal is received by rail and road and conveyed by belt conveyors to the bunkers or to the storage area.

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R 3 Adam (Swedish Nuclear Heat-Electric Station). P. H. Margen and H. Carruthers. *Tekn. Tidskr.* 1958, **88** (Nov. 11) 1077–84 (In Swedish).

A modified version of the original Adam district-heating station is now to proceed at Farsta, Stockholm. It will be a uranium-dioxide-fuelled, heavy-water reactor with initially 10 mw (e) and 55 mw (heat). After a few years, reactor capacity will be raised from 65 to 125 mw (heat) by inserting further cooling coils. Simultaneously, the turbine will be replaced by a new unit with condenser with, perhaps, an oil-fired superheater, giving 17 mw (e) with total condensation and 36 mw (e) when generating 70 mw (heat) for the heating water. Sections deal with possible alternative designs considered, mechanical construction, fuel handling arrangements, features of the thermal cycle, reactor data, and anticipated operating costs.

From *C.E.G.B. Digest* 1959, 11 (Jan. 17) 148.

Materials and Manufacturing Processes

High Temperature Metals. E. Skinner. *Chem. Engng.* 1958, **65** (Dec. 15) 137–47.

A summary supported by tables and graphs of available materials, their properties, resistance to high temperature and attack by various chemicals, including a literature review.

A New Material for High Pressure Steam Pipelines. R. Franzl. *Energie & Technik* 1958, **10** (Dec.) 396–8 (In German).

A new ferritic steel X20 Cr Mo V W 121 has been introduced in Germany and is mainly intended for the temperature range 530-575 C (985-1070 F) in which is it more economic to use than other ferritic or austenitic steels. Its composition is: 0.17–0.23 per cent C, 0.5 per cent Si, 1 per cent Mn, 11–12.5 per cent Cr, 0.8–1.2 per cent Mo, 0.3–0.6 per cent Ni, 0.25–0.35 per cent V and 0.4–0.6 per cent W. Strength data for temperatures up to 600 C are given.

High Temperature Resistant Ferritic Steels. P. Bettzieche. *Mitt. V.G.B.* No. 57 1958 (Dec.) 393–7 (In German).

Results of tests on Mo-V and 12 per cent Cr steels for service at temperatures up to 600 C (1100 F) are presented and their fields of application discussed. The 12 per cent Cr steel is specially suitable for the highest temperatures at lower pressures or for lower temperatures at high pressures, where austenitic steels would be uneconomic. Fabrication, welding and heat-treatment procedures for the two steels are given.

Heat Resistant Cast 12 Per Cent Chromium Steel. R. Schinn. *Mitt. V.G.B.* No. 57 1958 (Dec.) 397–404 (In German).

The use of this 12% Cr steel for steam turbines is discussed.

Results of Co-Operative Investigations "Long-Term Creep Rupture Tests." Conclusions for Boiler Fabrication. W. Ruttmann and R. Schinn. *Mitt. V.G.B.* No. 57 1958 (Dec.) 411–20 (In German).

A total of 1136 samples of 65 different steels are being subjected to long-term creep rupture tests by four laboratories. The tests have been

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extended to temperatures of 750 C (1400 F) and some have now reached 60,000 h. The results obtained so far are reproduced in graphs. It is concluded that it is necessary to continue the tests to 100,000 h since extrapolation of short-term tests are not regarded as sufficiently reliable. Some tests should be extended beyond 100,000 h to see if extrapolation of 100,000 h tests to longer times is admissible.

Thermal Shock Tests on Austenitic-Ferritic Joints. R. Schinn and W. Ruttmann. *Mitt. VGB.* No. 57 1958 (Dec.) 407–11 (In German).

Thermal shock tests were made on the austenitic ferritic joints, developed by Mannesmann, under conditions much more severe than likely to be encountered during operation. Despite this no separation of the metals in the joints was found.

Mechanised Surfacing with Alloy Materials. R. S. Zuchowski and J. H. Neely. *Weld. J.* 1959, **37** (Jan.) 22–9.

Techniques developed for automatically depositing various metals and alloys are described. By use of multiple welding wires and powder alloys

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the composition of the deposits can be varied within wide limits.

Contribution to the Joining of Clad Metals and to Lining Techniques. H. Gerbeaux. *Soudage* 1958, **12** (Nov./Dec.) 441–59 (In French).

Cutting, preparation and welding of clad steels are described and stress conditions for various materials and types of assemblies are dealt with. Strong linings and thin dressings developed for certain apparatus are also considered.

Pressure Welding of Metals. Various Authors. *Brit. Weld. J.* 1959, **6** (Jan.) 1–37.

The papers to the conference held at Birmingham University on June 19, 1958 are reprinted:

1. Introductory Survey, by E. C. Rollason.
2. Industrial Practice in Cold Pressure Welding, by J. A. Donelan.
3. Pressure Welding by Rolling, by L. R. Vaidyanath, M. G. Nicholas and D. R. Milner.
4. Influence of Relative Interfacial Movement and Frictional Restraint in Cold Pressure Welding, by E. Holmes.

Welding and Heat Treatment During the Construction of Steam Generators in the Workshop, on the Site and During Repairs. H. D. Weise. *Mitt. V.G.B.* No. 57 1958 (Dec.) 420–4 (In German).

Practical hints are given for the selection of the best welding method, preparation and heat treatment of welds. The differences in welding procedures used in workshops and on the sites are pointed out. Many difficulties encountered in welding could be obviated, if designers would pay more attention to welding problems.

Effect on Fatigue Strength of Internal Defects of Welded Joints. A Survey of the Literature. R. P. Newman. *Brit. Weld. J.* 1959, **6** (Feb.) 59–64.

The influence of defects in butt welds in mild steel plate on fatigue strength is considered on the basis of a survey of the relevant literature.

Effect of Welding and Stress Relief on the Parent Plate. J. E. Roberts. *Brit. Weld. J.* 1959, **6** (Feb.) 72–81.

Extensive studies of comparison of the mechanical properties of the heat affected zone and of the parent plate are reported for several kinds of steel, especially the effects of stress relief on initiation of brittle fracture.

Effect of Preheating and Postheating on Toughness of Weld Metal. T. N. Armstrong and W. L. Warner. *Weld. J.* 1959, **37** (Jan.) 27s-9s.

Results of tests on seven classes of steel electrodes are presented.

A Study of Metallurgical Effects in the Multipass Welding of Zircaloy. R. E. Johnson and B. W. Schaaf. *Weld. J.* 1959, **37** (Jan.) 1s-9s.

A thirty-two pass weld in a $2^1/_4$ in. thick Zircaloy-2 plate and welds in Zircaloy-2 and -3 were tested. In general the joint efficiency is 100 per cent, but ductility is slightly lowered and the mechanical properties may be impaired by certain deleterious post-weld heat treatments.

Instruments and Controls

Automatic Data Logging Expected to Cut Costs. S. A. Lyon. *Electr. World* 1958, **150** (Dec. 22) 46-7, 129.

At the Millikan power station containing two 150-mw units, data logging equipment has been installed which senses 256 temperatures and pressures every 5 min, compares each with a set limit and gives an alarm if necessary. Once every hour 267 instantaneous values are typed. A total of 59 instantaneous and 26 integrated values of performance are recorded every hour. All data are automatically punched into cards. This system relieves operators from time consuming repetitive tasks and gives them more freedom to take quick action based on accurate data.

The Control of Sulzer Monotube Steam Generators with Reheat. M. Diethelm. *BWK* 1959, **11** (Jan.) 3-7.

The oil hydraulic controls and additional remote electric controls from the control room developed for two reheat boilers (400 klb/h 2100 psi, 1015-1005 F, 940 klb/h 2650 psi, 1060-1010 F) are described. The automatic controls are operated by oil pressure, such that the oil pressure is proportional to the valve setting but this can be influenced or altered by electric impulse from the control room.

Measurement of Dust Concentration in Pneumatic Transport. R. Quack. *BWK* 1959, **11** (Jan.) 13.

The measurement of the concentration of pulverized coal in a vertical and a horizontal duct by means of β rays was studied. With pure air, the counter measured 150 impulses/sec, with increasing dust concentrations these were reduced to 43-5 impulses/sec. In the vertical duct the relationship between concentration and impulse/sec was linear, in the horizontal duct a curve was obtained from which it was deduced that the dust tended to concentrate on the bottom. Further studies with a stronger source are to be made to increase the accuracy and reduce the time lag.

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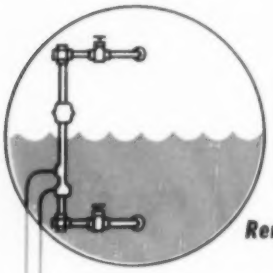

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Power 1959, **103** (Jan.) 75–7.

The system consists of a pneumatic transmitter and receiver-controller mounted on the actuator, with a transmitter installed at the point of measurement. This has reduced the time lag considerably.

Miniature Oil Velocity Indicator. A. J. S. Baker, R. Tourret and J. T. Jones. *Engineering* 1959, **187** (Jan. 16) 82–8.

The design of an instrument for measuring the velocity of oil in pipelines from the tank to the burners is described and calibration curves are presented.

Tube Cameras for Investigating Corrosion Problems. A. G. Arend. *Corrosion Prev. and Contr.* 1958, **5** (Dec.) 53–5.

An instrument for the inspection of the interior of tubes by means of a cinematograph camera has been developed, incorporating a mechanism which automatically shifts the observation tube backwards and forwards and indexes it by the required angle after each exposure traverse. Bores down to 3 in. diam. and even smaller can be inspected by the new camera.

Nuclear Energy

Reactors. Anon. *Nucl. Pwr.* 1959, **4** (Jan.) 113–20.

A series of tables is presented of all reactors (power and research) of which any details have been published, classified mainly by moderator and giving name or owner, first loading, location, principal contractor, thermal output, maximum neutron flux, fuel, reflector, coolant and notes.

The Major Atomic Countries. Anon. *Nucl. Pwr.* 1959, **4** (Jan.) 94–112.

A survey is given of the nuclear power programs of all countries which have published any plans for the installation of nuclear power stations.

Atomic Review. Reactors Abroad. Anon. *Engineering* 1959, **187** (Jan. 16) 78–80.

Details are given of American reactors which commenced operation or were under construction in 1958. These include several ship propulsion reactors, a high temperature reactor, a pressurized water reactor, the special power excursion reactor test No. 3 (Spert III), the boiling water reactor with superheater for Puerto Rico and the dual-core reactor. The Japanese design for the core of a reactor of the Calder Hall type to resist earthquakes is briefly discussed. Notes on developments in Mexico, the Netherlands, New Zealand and Norway are added.

Making the Best Use of Nuclear

Fuels. M. D. Jepson. *Atomic World* 1959, **10** (Jan.) 14–7.

A classification of reactors according to the fuel system is proposed. The systems differ by primary fuel, fertile material and secondary fuel products. The best ways of using the secondary fuels are discussed.

Euratom: The European Atomic Energy Community. L. Armand. *Nucl. Pwr.* 1959, **4** (Jan.) 88–90.

The reasons for setting up the Euratom organization and the work to be performed by it are presented.

The European Nuclear Energy Agency P. Huet. *Nucl. Pwr.* 1959, **4** (Jan.) 90–1.

The projects with which the Agency will deal are described and the organization set up for these purposes is outlined.

Steps in Designing a Gas-Cooled Reactor. K. J. Wootton. *Nucl Pwr.* 1959, **4** (Feb.) 64–9.

The design consideration for a 150 mw gas cooled, graphite moderated reactor are set out under the headings: (1) Type of fuel element and its support; (2) Reactor parameters and optimum combination; (3) Blower power limit; (4) Pressure vessel; (5) Protection of the vessel; (6) On-load fuelling; (7) Number of control rods; (8) Skirt design; (9) Blower speed control; (10) Flexibility.

Wigner-Energy Storage. Its Relation to Reactor Design. P. J. Grant. *Nucl. Engng.* 1959, **4** (Feb.) 69–72.

The phenomenon of Wigner energy storage is discussed and the design adopted for the Hunterston nuclear power station to allow for raising the graphite temperature of the fuel element sleeves is described.

The Future of Boiling Water Reactors. J. M. West and G. M. Roy. *Nucleonics* 1959, **17** (Jan.) 42–9.

Based on experiences with EBWR and Borax IV the future of the pressurized water reactor is discussed. Modifications to improve its efficiency and reduce its cost are reviewed. For smaller reactors natural circulation would be sufficient, but larger ones would require forced circulation. For plants of about 24 mw (electric) the cost would be $300–$330 kw (e), for plants of 200 mw it would be $250–$300 kw and for still larger plants, the cost may be reduced to about $200 kw. In the discussion, the large influence of fuel fabrication, utilization and re-processing on overall economics is stressed.

Fast Oxide Breeder Fuel Cycle and Cost. J. K. Davidson, R. S. Miller and D. J. Smith. *Nucleonics* 1959, **17** (Jan.) 88–93.

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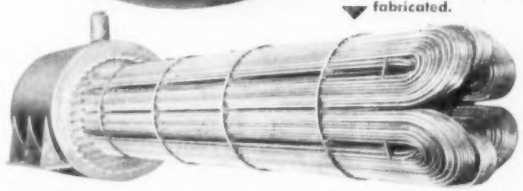

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An attempt is made at estimating the actual operating and fuel-cycle costs of a fast breeder reactor with a UO_2-PUO_2 core and some details of the design of the reactor are given.

Liquid Metal Fuel Reactor Experiment. H. H. Poor. *Nuclr. Pwr.* 1959, **4** (Feb.) 84.

Brief details are given of the liquid metal fuel reactor (LMFR) which will use U 235 dissolved in liquid bismuth as fuel. The fuel leaves the reactor at 488 C and returns via heat exchangers at 413 C. The heat is transferred to liquid bismuth and from this to air. The advantages and disadvantages of this type of reactor are discussed.

Planning and Operating a Critical Facility. F. J. Jankowski and J. W. Chastain. *Nucleonics* 1958, **16** (Dec.) 48–50.

Advice is given on the preliminary steps to be taken before setting up a critical facility and also on factors to be considered during the operation.

Multi-Unit Steam Generators. W. B. Sallitt. *Nucl. Engng.* 1959, **4** (Feb.) 66–8.

The installation of multi-unit steam generators instead of one large one has the advantage that this can be completely shop-fabricated under clean conditions. This design has been adopted in France for the E.D.F.1 where 120 units are installed for the 75-mw (e) reactor. The design, construction and installation of these steam generators are described.

Analysis and Testing, Research

Fog Generation for Leakage Testing of the Gas-Side of Boilers. H. Trenkler. *Mitt. V.G.B.* No. 57 1958 (Dec.) 424–5 (In German).

An apparatus is described with all essential dimensions which is being used at the Fortuna power stations to test the boiler passes for freedom from leakage. The apparatus has a capacity of 565 cu ft/min at a pressure of 8 in. w.g. and injects by means of compressed air $SiCl_4$ or $TiCl_4$ and a 25 per cent ammonia solution in the ratio of 1:3. Generally $SiCl_4$ which costs only $\frac{1}{5}$ of $TiCl_4$ is used, but where heavier fogs are required the latter must be employed. The filling of a 1000 klb/h boiler takes 45 min and 13 lb of liquids. The fog is not injurious to either the boiler materials or the operators.

A Critical Analysis of Pitting Corrosion. N. D. Greene and M. G. Fontana. *Corrosion* 1959, **15** (Jan.) 41–7.

A critical analysis of the literature published during the past 35 years and a consideration of the definition of pitting and factors influencing this type of corrosion.

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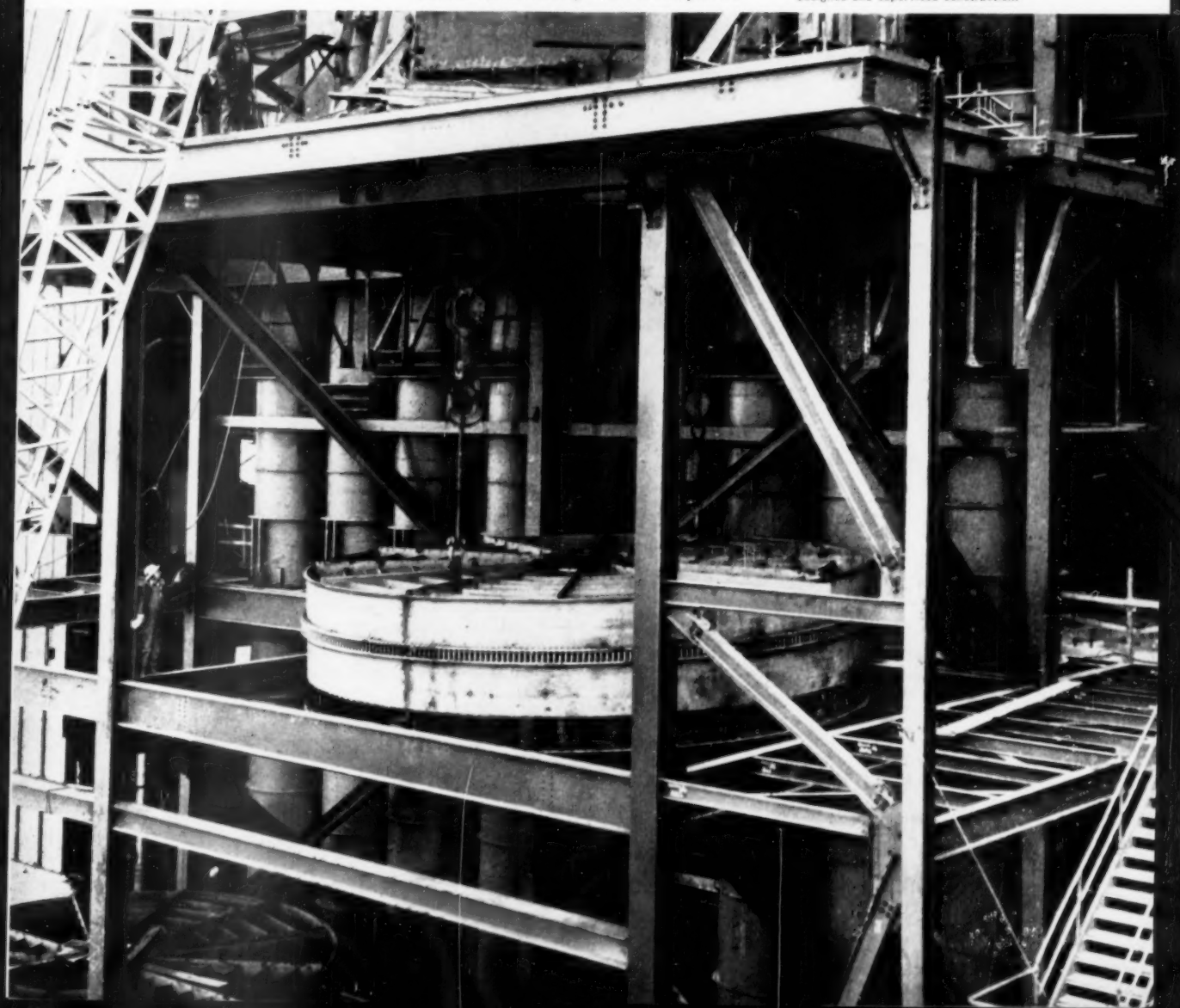
Ljungstrom rotor being installed for the City of Memphis Light, Gas and Water Division. Six such Ljungstroms—each with 201,400 sq ft of heating surface—will serve three boilers. The boilers will each evaporate 2,000,000 lbs of steam/hr and have a combined nameplate capacity of 750,000 kw. A fourth boiler unit is now under consideration. Burns and Roe, Inc. designed and supervised construction.



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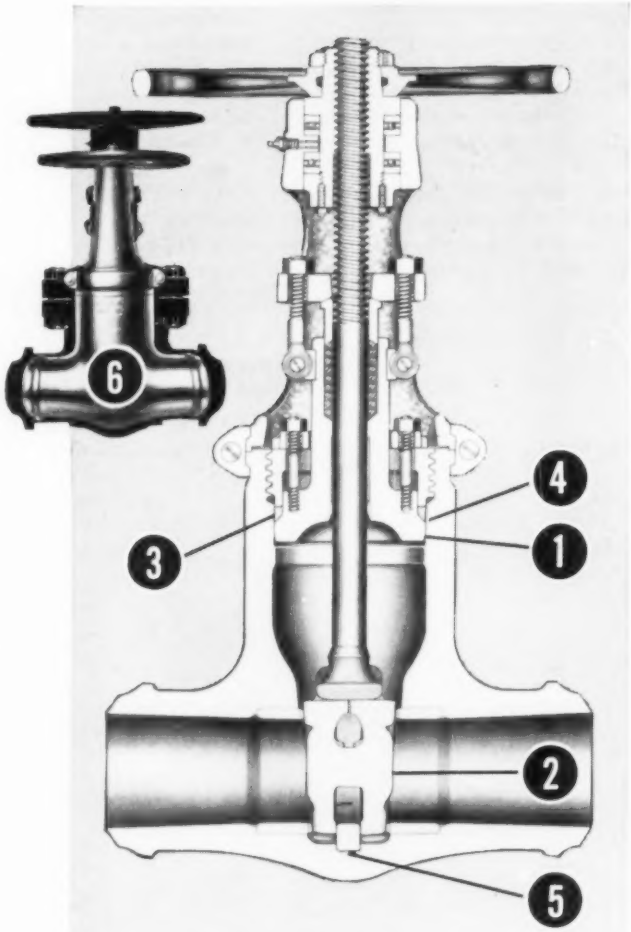
In Crane Pressure-Seal bonnet gate valves it is:

1. **using internal pressure to seal the bonnet joint —the higher the pressure, the tighter the seal —eliminates bonnet-joint maintenance**
2. **a flexible wedge disc that prevents sticking when valve is closed hot and opened cold . . . doesn't jam even when seated with excessive torque**
3. **a one-piece, silver-plated seal ring held snugly in place by a chrome-plated retaining ring which is screwed into the body; ring remains freeze-free for easy dismantling**
4. **a wear-resisting stainless steel inlay in the body adjacent to the seal ring that insures tight sealing and maximum protection against corrosion at this important point**
5. **full-travel disc guiding—even at critical point of final closure; prevents wear and drag on seating surface**
6. **streamlined, weight-saving design—saves up to 60% of weight of conventional bolted bonnet valves . . . reduces suspension cost . . . simplifies insulating**

Crane 1500-pound Pressure-Seal bonnet globe and angle valves: 1" to 16"; socket- and butt-welding ends.

Crane's complete, expanded line of Pressure-Seal bonnet valves includes gates, globes, angles, globe lift-checks and stop-checks—in all standard sizes, ends and pressure classes. For complete information, see your Crane Representative.



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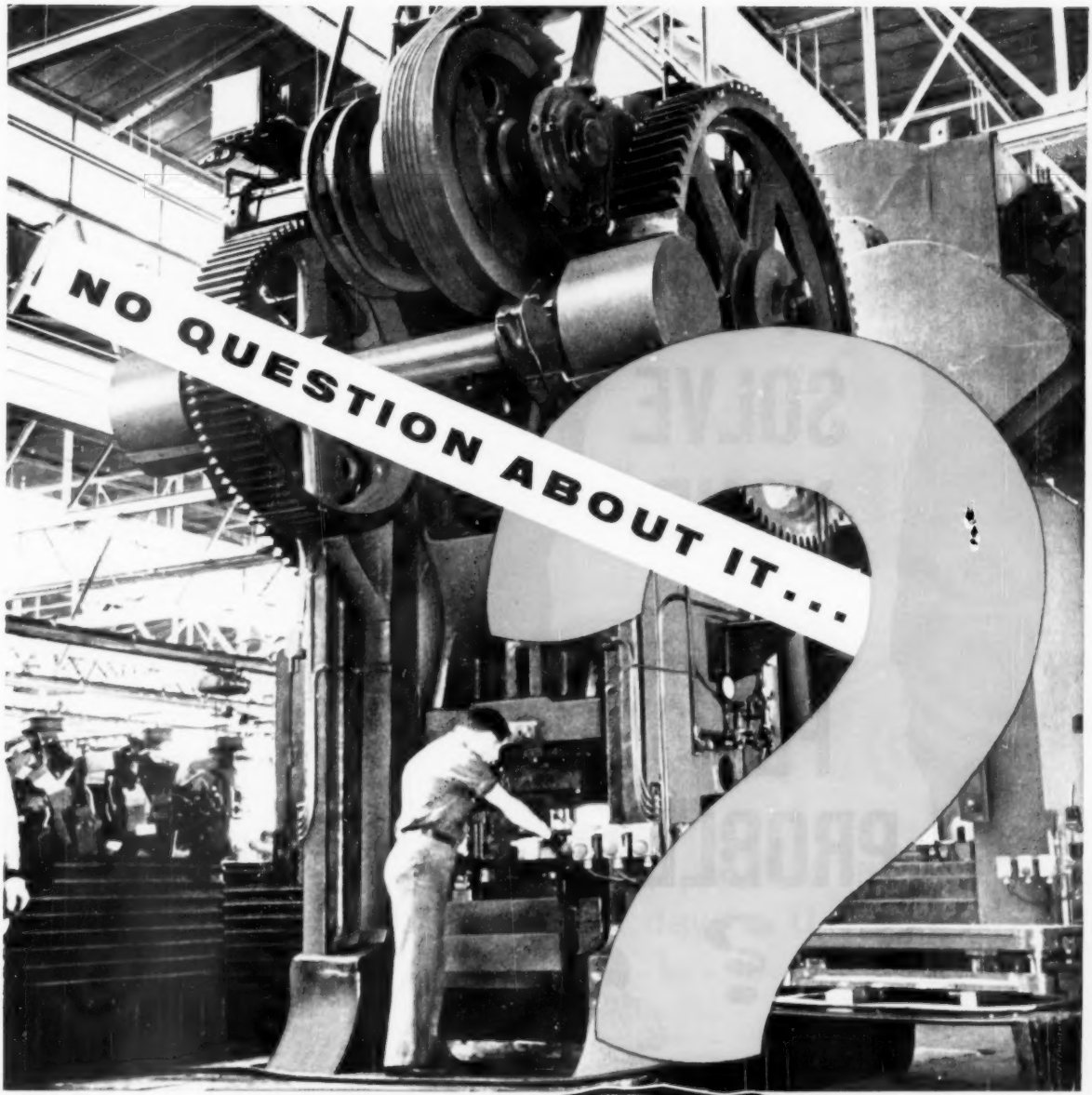

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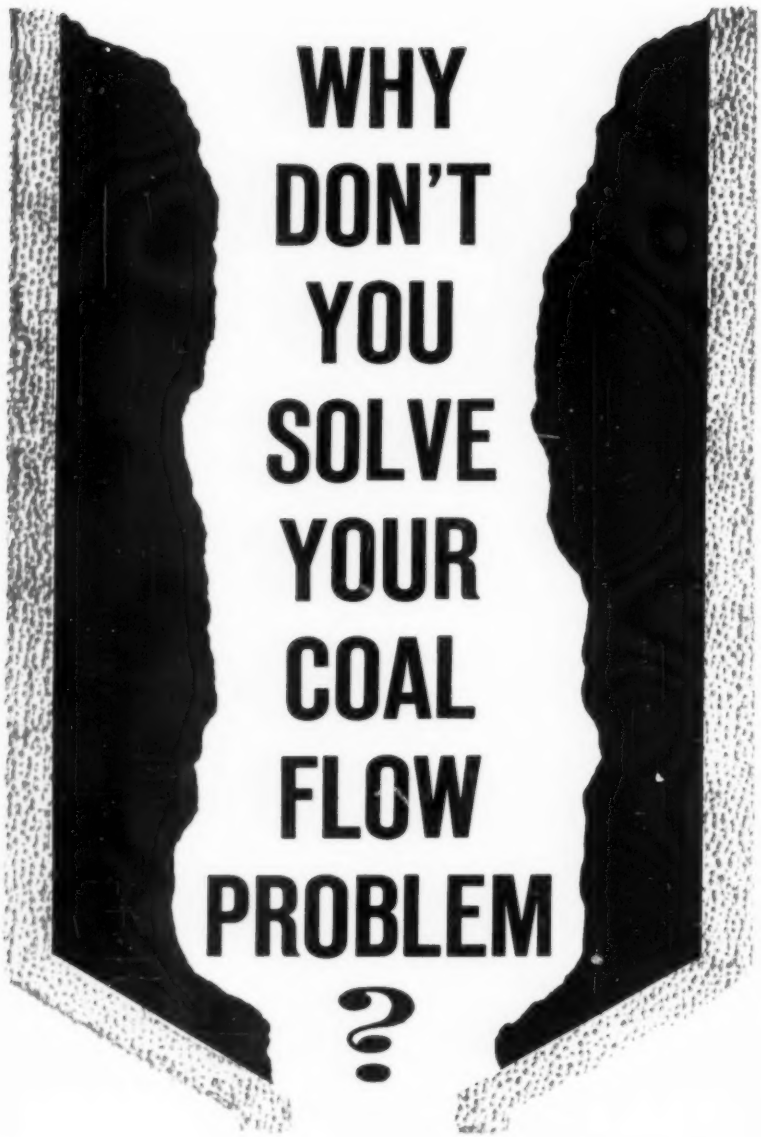

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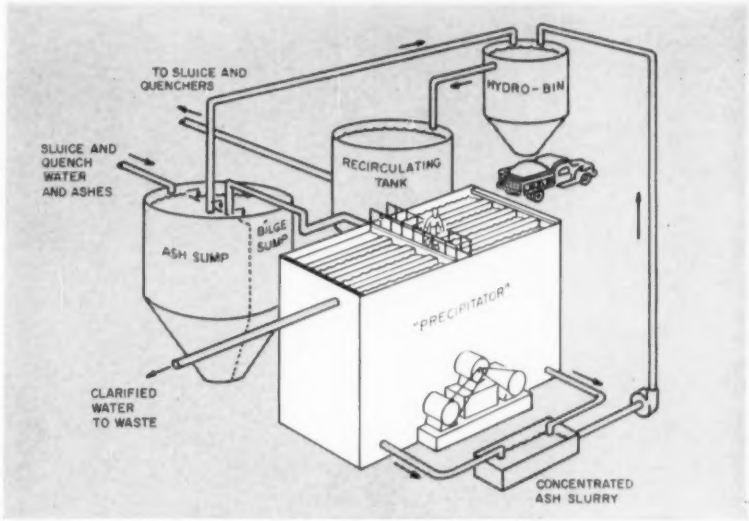

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. . . makes ash-handling system flexible, dependable.

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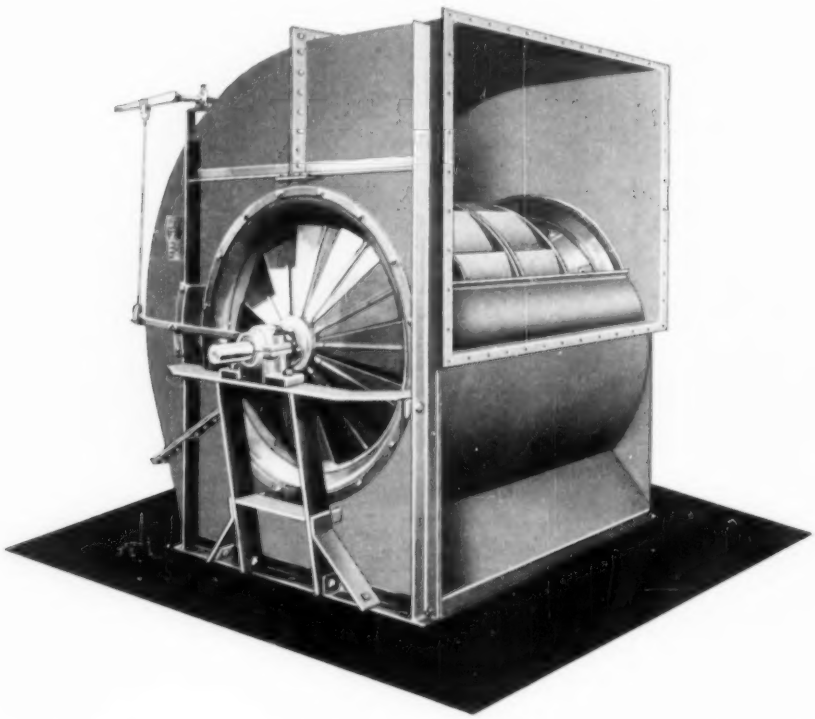

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- *Low maintenance.* Servicing the Color-Port is simple as A-B-C. With gage remaining in place, individual cover plate assemblies can be inserted in a matter of minutes. Exclusive spring loading maintains proper pressure on glasses and gaskets at all times.
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Replace troublesome water level gages with the new medium pressure Yarway Color-Port—and for your new boilers, make sure the specifications read YARWAY COLOR-PORT. Visibility ranges of *13"*, *15½"* and *18"* available.

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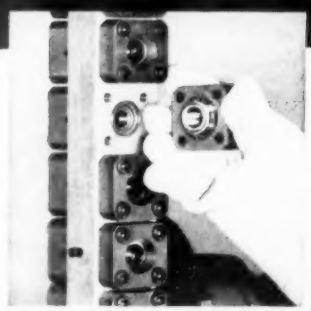
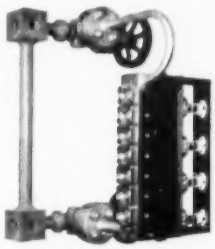


Complete cover plate assemblies can be replaced in minutes, with the gage in place.



Complete Color-Port assembly, with tie bar column, Welbond Gage Valves and Yarway Illuminator

YARWAY

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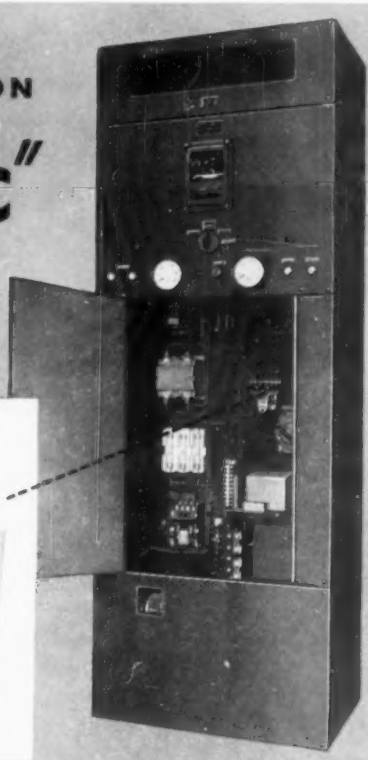
"Transistomatic" CONTROL



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